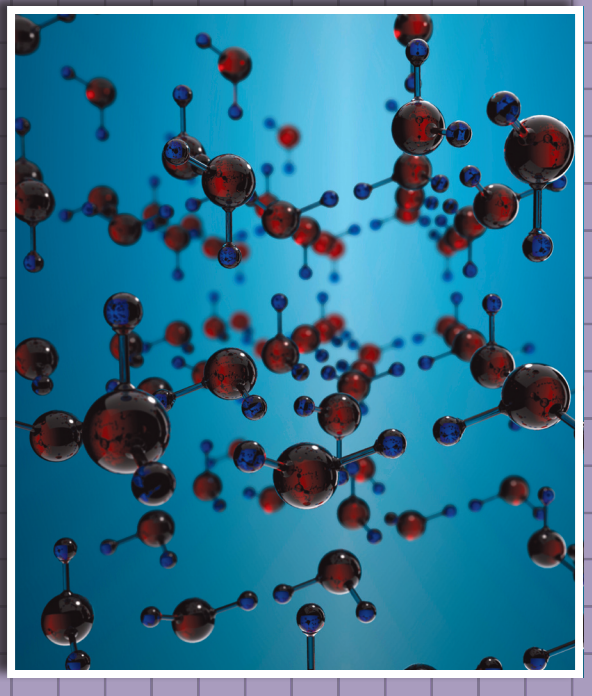
Principles and Practices of Water Supply Operations

Basic Science Concepts and Applications



Student Workbook

American Water Works Association

The Authoritative Resource on Safe Water®

Advocacy
Communications
Conferences
Education and Training
Science and Technology
Sections

Basic Science Concepts and Applications

Student Workbook

American Water Works Association

Basic Science Concepts and Applications Student Workbook
Principles and Practices of Water Supply Operations Series

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Basic Science Concepts and Applications Student Workbook

Principles and Practices
of Water Supply Operations Series

American Water Works
Association

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Foreword

This workbook is designed for use with the text *Basic Science Concepts and Applications*, fourth edition. This edition contains basic reviews of mathematics, hydraulics, chemistry, and electricity fundamental to water utility operation, as well as explanations and examples of many specific water system operating problems.

Other volumes in the series are

- *Water Quality*
- *Water Treatment*
- *Water Transmission and Distribution*
- *Water Sources*

The student workbooks were added to the series in conjunction with the third edition updating of the texts. The author of the first edition of the Student Workbook was Todd Shimoda. Revision for the second edition of the Student Workbook is provided by Nancy McTigue.

Introduction: Using Your Student Workbook

This *Student Workbook* is provided to assist you in studying the basic concepts of mathematics, hydraulics, chemistry, and electricity that are fundamental to water utility operations. If you carefully maintain your own personal workbook with notes and supplemental information, you will likely reference it throughout your water utility career.

FORMAT

This workbook provides the following for each section of the text:

- *Objectives*. This is a listing of some of the major concepts that you should be able to identify and explain when you have completed study of the chapter. You should preview the list at the beginning of study to assess what will be covered. You should then review it again when you have completed study of the chapter to see if you adequately understand the listed concepts.
- *Reading Assignment*. An assignment is given indicating the chapter from *Basic Science Concepts and Applications* that should be read in conjunction with the study of the workbook chapter.
- *Other Assignments*. If you are attending a class, this space can be used to make a record of additional reading and study assignments given by the instructor. If you are using this workbook for self-study, you can make notes for future reference on additional sources of information.
- *Class Notes*. Space has been provided for you to keep notes of points you feel are important as you read the text or of points made by the instructor during class discussions.
- *Review Questions*. The review questions are intended to emphasize some of the important concepts in the chapter. Diagrams of ion exchange plants and a lime–soda ash softening plant, along with questions pertaining to these sample diagrams, are also included at the end of the workbook.
- *Additional Notes*. Each chapter concludes with extra space for note taking.

TEXTS AND REFERENCES

It will be necessary for you to have a copy of *Basic Science Concepts and Applications*, fourth edition, available while studying the subject. You should also have access to the other volumes in the series Principles and Practices of Water Supply Operations. If the copies you are using belong to your water utility or someone else, it is best not to mark or highlight in the books. Your notes on important points can instead be made in the workbook.

If you are presently working for a water utility, you probably have access to old editions and copies of some texts that are no longer in print. You will find it is helpful to look through these books and read about subjects you are studying, using this workbook. Sometimes, there may be more detail, or subjects may be presented in a different way in another text. You must be aware, though, that water treatment technology and state and federal regulations have changed greatly in recent years, so some information in an older text may no longer be valid.

USE OF THE WORKBOOK

If you are using this workbook in conjunction with class instruction, you are urged to keep a loose-leaf notebook for supplementary sheets distributed by the instructor, filed in the order in which the subjects are studied. When your notes are carefully kept in order, they provide an excellent personal information source for later review and reference.

The review questions are designed to highlight some of the major points of each chapter. You should reread sections covered by the review questions until you can completely answer the questions. The instructor will then review the answers during a class period to make sure everyone understands the subject and has provided the correct answers.

Your instructor usually will also provide supplemental assignments and furnish handout material for each chapter. When the length of class meetings is limited, some chapters will be broken into segments and covered during two or more meetings.

The workbook can also be used for individual study. Notes should be made of important points as the text and references are read, and the review questions should be answered completely to ensure that the full significance of important points is understood.

STATE AND FEDERAL REGULATIONS

Many aspects of water treatment and distribution system operations are now directed and regulated by federal regulations. A review of federal regulations is provided in *Water Quality* (another volume in this series). But many changes are expected within coming years.

Although the states are generally required to enact regulations that are as stringent as the federal requirements, the state regulations may, at times, vary, be more stringent, or include additional requirements. It is therefore important that you obtain a reference copy of the latest state drinking water regulations for the state in which you are working. Applicable sections of the regulations should then be reviewed in conjunction with your study of each chapter.

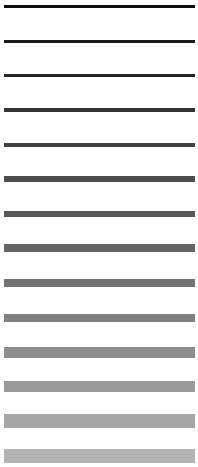
QUIZZES AND EXAMINATIONS

If you are attending training classes, the instructor will probably give you a few quizzes during the course. These are important to you in indicating whether you are adequately learning the material being presented; they are also important to the instructor to determine if the material is being properly presented.

If you are studying this subject in preparation for taking a state certification examination, it is particularly important that you become comfortable in taking exams of the type used by the state. If you would like more review and practice in answering questions of the type used on certification exams, it is suggested that you obtain the AWWA publication *Operator Certification Study Guide*.

Good Luck in Your Water Utility Career!

Mathematics



Basic Math for Operators

INTRODUCTION

Working in the field of water treatment involves mathematical problem solving. The mathematics presented in this review section are basic concepts that, when mastered, will be useful in other areas.

OBJECTIVES

Upon completion of this lesson, you should be competent in working with the following mathematical concepts:

1. Simple arithmetic—addition, subtraction, multiplication, and division
2. Fractions
3. Decimals
4. Percents
5. Ratios and proportions

Also included is information on perimeters, conversion factors, and math terminology. You are advised to work on the problems in this lesson *without* the aid of an electronic calculator. The goal of this lesson is to exercise your mental abilities. Use the calculator only to check your work.

SIMPLE ARITHMETIC

Addition

The following three rules generally apply when adding whole numbers.

Rule 1: Keep all decimal points and numbers in columns.

Example:

18.45	3,348.90	0.36
+ 1.41	+ 151.06	+ 0.02
19.86	3,499.96	0.38

Rule 2: Write down all carryover numbers.

Example:

^{1}	$^{1\ 1\ 1}$	$^{1\ 1}$
373	2,935	0.67
+ 119	+ 988	+ 0.36
492	3,923	1.03

Carryover numbers should be written down lightly. Also note the position of the carryover number in relation to the other numbers.

Rule 3: All numbers *must* be in the same units (add inches to inches, feet to feet, hours to hours, and apples to apples).

Example: Find the answer to the problem 3 ft plus 7 yd.
Incorrect method:

3 ft
+ 7 yd
10 ????

Correct method:

Option 1

a. Convert all units of measurement to feet.

3 ft
+ 7 yd: How many feet are in a yard?
3 ft = 1 yd

Conversion:

$7\ \cancel{\text{yd}} \times 3\ \frac{\text{ft}}{\cancel{\text{yd}}}$ = 21 ft (the unit of yards cancels out.)

b. Now add the converted measurement to the 3 ft.

21 ft + 3 ft = 24 ft

Option 2

a. Convert all units of measurement to yards.

3 ft: How many feet are in a yard?
3 ft = 1 yd
+ 7 yd

Conversion:

$\frac{3\ \cancel{\text{ft}}}{3\ \cancel{\text{ft}}}$ = number of yards = 1 yd

b. Now add the converted measurement to the 7 yd.

1 yd + 7 yd = 8 yd

Subtraction

Subtraction is the reverse operation of addition. The three rules for addition also apply to subtraction.

Rule 1: Keep all decimal points and numbers in columns.

Examples:	3.769	1,237.78	0.569
	– 0.527	– 27.75	– 0.130
	3.242	1,210.03	0.439

Rule 2: Write down all borrowed numbers. In subtraction you do not carry over numbers, but sometimes you must borrow numbers.

	Step 1	Step 2	Step 3	Step 4
Examples:	953	953	$\overset{8}{\cancel{9}}\overset{1}{5}3$	$\overset{8}{\cancel{9}}\overset{1}{5}3$
	– 371	– 371	– 3 71	– 3 71
		2	82	5 82

Step 1 presents the problem to be solved.
Step 2 shows subtraction in the first column of numbers.
Step 3 shows subtraction in the second column of numbers. In this step, 1 had to be borrowed from the third-column number. Now the number 7 is subtracted from the number 15.
Step 4 shows that in borrowing from the third-column number, the number 9 was reduced to the number 8. Now the number 3 is subtracted from the number 8.
The final answer is 582. Now check the subtraction by adding the final answer to 371. You should obtain the number 953.

Rule 3: All numbers *must* be in the same units (i.e., do not subtract apples from oranges).

Multiplication

Multiplication can be thought of as an advanced form of addition. Multiplication is an accelerated process by which to add a number to itself numerous times.

Example:

4			
4			
4			
4	or		4
+ 4			× 5
20			20

It is advantageous to memorize the multiplication tables from 1 through 10, if you have not already done so.

When multiplying large numbers, multiply one set of numbers at a time. The following steps show how this can be accomplished:

Example: What is 89 × 31 = ?

Step 1	Step 2
89 (multiply 9 × 1 = 9)	89 (multiply 8 × 1 = 8)
× 31	× 31
9	89

Step 3

$^{2}89$ (Multiply $3 \times 9 = 27$. Place 7 in the next row, one column
$\times\ 31$ to the left. Carry over 2 to 8.)

89

70 (Insert 0 as a placeholder.)

Step 4

$^{2}89$ (Multiply $8 \times 3 = 24$. Add 2, which was carried over, to 24
$\times\ 31$ to obtain 26. Place this number to the left of 7.)

89

2,670

Step 5

$^{2}89$ (Add 89 and 2,670 to obtain the final answer.)

$\times\ 31$

89

2,670

2,759

There are two rules to remember in multiplication:

Rule 1: The number of decimal places in the answer is equal to the sum of decimal places in the numbers multiplied.

Example:

17.059	(3 decimal places)	
$\times$ 2.75	(+ 2 decimal places)	
85295	(5 decimal places)	
1194130		
+ 3411800		
46.91225		

The decimal is placed five places from the right. The answer is 46.91225.

Rule 2: Unlike addition and subtraction, multiplied numbers do not have to have similar dimensional units. Thus, one must specify the units that go with the numbers. These *must* be carried through to the answer.

Example: A 7-ft lever with a 15-lb weight on its end would produce
7 ft $\times$ 15 lb = 105 ft-lb of pressure.

Always remember to carry the units through to the answer. This will aid in working the math problem with a variety of different units.

Multiplication may be indicated in any one of the following ways:

Sign	Example
1 ×	50 × 10 × 2 = 1,000
2 ( )	(50)(10)(2) = 1,000
3 [ ]	[50][10][2] = 1,000
4 *	50 * 10 * 2 = 1,000
5 ·	50 · 10 · 2 = 1,000
6 any combination	(50)10 × 2 = 1,000
	[50 * 10]2 = 1,000
	50 · 10[2] = 1,000

If the brackets [ ] or parentheses ( ) are used, be sure to complete the operation within the brackets or parentheses *first*.

Examples: (35 – 5) (5 · 3) (8 + 2) =

(30) (15) (10) =

or

30 × 15 × 10 = 4,500

[200 + (5 · 2) (8 – 3)] [9 * (2 + (6 × 5))] =

[200 + (10) (5)] [9 * (2 + (30))] =

[200 + 50] [9 * (32)] =

[250] [288] = 72,000

Division

Division is another method of subtraction. Dividing 20 by 5 is the same as finding how many times 5 can be taken away from 20.

Example:

20 – 5 = 15 (one)

15 – 5 = 10 (two)

10 – 5 = 5 (three)

5 – 5 = 0 (four)

This same operation can be accomplished using division:

Step 1 The number 5 cannot divide into 2, but it will divide into the number 20 four times.

$$5\overline{)20}\quad 4$$

Step 2 Multiply 5 by 4 and write the answer under the number 20.

Subtract the result of 5 × 4 from the number 20. The remainder is 0. The answer is 4.

$$\begin{array}{r} 4 \\ 5\overline{)20} \\ \underline{20} \\ 0 \end{array}$$

The division process can be indicated in one of the following formats:

1. $5\overline{)20}$ (4)
2. $\frac{20}{5} = 4$
3. $20 \div 5 = 4$
4. $20/5 = 4$

In the above examples, 5 is the divisor, 20 is the dividend, and 4 is the quotient.

4 (Quotient)
(Divisor) 5)20 (Dividend)

When dividing numbers that contain decimals, the following rule applies:

Rule 1: Move the decimal point in the divisor all the way to the right and move the decimal point in the dividend the same number of places to the right.

Example: Divide 2.255 by 0.05

Step 1 Move the decimal point two places to the right in the divisor and the dividend.

$0.05\overline{)2.255}$

Moving the decimals results in $5\overline{)225.5}$

Step 2 5 will not divide into 2 but will go into 22 approximately four times.

$$\begin{array}{r} 4 \\ 5\overline{)225.5} \end{array}$$

Step 3 Multiply 5 by 4 and subtract the answer from 22.

$$\begin{array}{r} 4 \\ 5\overline{)225.5} \\ \underline{20} \\ 2 \end{array}$$

Step 4 Bring down the 5.

$$\begin{array}{r} 4 \\ 5\overline{)225.5} \\ \underline{20}\downarrow \\ 25 \end{array}$$

Step 5 5 will go into 25 five times. Note that the decimal in the quotient is placed directly over the decimal in the dividend.

$$\begin{array}{r} 45. \\ 5\overline{)225.5} \\ \underline{20} \\ 25 \end{array}$$

Step 6 Multiply 5 by 5 and subtract the answer from 25.

```
   45.
5 )225.5
  20
  25
  25
   0
```

Step 7 Bring down the 5; 5 will go into 5 once.

```
   45.1
5 )225.5
  20
  25
  25
   0 5
```

Step 8 Multiply 5 by 1 and subtract the result from 5.

```
   45.1
5 )225.5
  20
  25
  25
   0 5
     5
```

When solving a division problem, complete the indicated operations above and below the division line before dividing.

For example:

$$\frac{50 - (2)(5) + \frac{15}{3}}{17 - (2)(3) - 1} + \frac{(6)(3)}{9} =$$

$$\frac{50 - 10 + 5}{17 - 6 - 1} + \frac{18}{9} = \frac{45}{10} + 2 =$$

$$4.5 + 2 = 6.5$$

FRACTIONS

A fraction is a part of a whole. When you cut a pipe into six equal parts and use five of those parts, you use 5/6 of the pipe.

The terms of a fraction are the *numerator* and the *denominator.*

$$\frac{5}{6}$$ (Numerator)

(Denominator)

A *proper fraction* has a value that is less than 1.

Examples: $\frac{3}{4}$ $\frac{5}{8}$ $\frac{7}{10}$

A *mixed fraction* contains a whole number and a fraction.

Examples: $2\frac{3}{8}$ $5\frac{5}{6}$

An *improper fraction* has a value that is equal to 1 or greater than 1. In this type of fraction, the numerator is equal to or greater than the denominator.

Examples:

Improper Fraction	Equal to
$\frac{4}{4}$	1
$\frac{8}{4}$	2
$\frac{5}{4}$	$1\frac{1}{4}$

To change an improper fraction to a whole number or to a mixed number, divide the numerator by the denominator. When there is a remainder, write it over the denominator.

Examples: $\frac{25}{5} = 5$ $\frac{27}{5} = 5\frac{2}{5}$

To change a mixed number such as $5\frac{7}{8}$ to an improper fraction, use the following steps:

Step 1 Multiply the whole number by the denominator of the fraction.

$5 \times 8 = 40$

Step 2 Add the product to the numerator.

$40 + 7 = 47$

Step 3 Write the results over the denominator.

$\frac{47}{8}$

In the following example, how do you change a whole number such as 5 to an improper fraction?

1. $5 = \frac{?}{25}$

2. $5 \times 25 = 125$

3. $125 + 0 = 125$

4. $\frac{125}{25}$

A fraction is in its *lowest term* when there is no divisor that is common to both numerator and denominator as 2/5, 5/8.

A fraction can be rounded to its lowest term by dividing the number that is contained exactly in both. In other words, divide the numerator and the denominator by the largest number that will divide evenly into both. 2 is the divisor that is common to both the numerator and the denominator.

Example: $\frac{6}{8} = \frac{6 \div 2}{8 \div 2} = \frac{3}{4}$

Remember, the numerator and the denominator can be divided or multiplied by the same number *without* changing the value of the fraction.

Sometimes it takes several steps to reduce a fraction to its lowest terms. In this case, division continues until it can no longer be performed by a number larger than 1.

Example: $\frac{400}{480} = \frac{400 \div 4}{480 \div 4} = \frac{100}{120} = \frac{100 \div 10}{120 \div 10} = \frac{10}{12} = \frac{10 \div 2}{12 \div 2} = \frac{5}{6}$

To change a mixed number such as $7\frac{9}{4}$ into its simplest form:

Step 1 Simplify the fraction.

$$\frac{9}{4} = 2\frac{1}{4}$$

Step 2 Add the whole number to the result.

$$7 + 2\frac{1}{4} = 9\frac{1}{4}$$

A fraction can be changed to higher terms by multiplying both terms of the fraction by the same number.

Example: $\frac{2}{3} = \frac{2 \times 2}{3 \times 2} = \frac{4}{6} = \frac{4 \times 3}{6 \times 3} = \frac{12}{18} = \frac{12 \times 2}{18 \times 2} = \frac{24}{36}$

Addition and Subtraction of Fractions

Fractions must have a common denominator *before* they can be added or subtracted. In adding or subtracting fractions, simply add or subtract the numerators.

Examples: $\frac{4}{7} + \frac{3}{7} = \frac{7}{7} = 1$ $\frac{7}{9} - \frac{5}{9} = \frac{2}{9}$

If the denominators are not the same, they represent different units of measurement. Therefore, the denominators must be converted to a common unit before addition or subtraction can take place. The numerator and the denominator must be multiplied by the same number to change the form of the fraction while leaving the value of the fraction the same.

Examples: $\frac{2}{5} + \frac{6}{10} = \frac{2(2)}{5(2)} + \frac{6}{10} = \frac{4}{10} + \frac{6}{10} = \frac{10}{10} = 1$

$$\frac{1}{3} - \frac{2}{9} = \frac{1(3)}{3(3)} - \frac{2}{9} = \frac{3}{9} - \frac{2}{9} = \frac{1}{9}$$

Sometimes the denominators cannot be changed to one of the problem's existing denominators. In this case, the denominators must be changed to the common denominator. This means that the denominator is changed to the smallest number that each denominator will go into one or more times without a remainder.

Example: $\frac{2}{5} + \frac{1}{4}$

The smallest number that both 5 and 4 will go evenly into is 20; 5 will go into 20 four times.

$$\frac{20}{4} = 5$$

4 will go into 20 five times, $\frac{20}{4} = 5$

Therefore, $\frac{2 \times 4}{5 \times 4} + \frac{1 \times 5}{4 \times 5} = \frac{8}{20} + \frac{5}{20} = \frac{13}{20}$

Multiplication and Division of Fractions

In multiplying fractions:

1. Change mixed numbers to improper fractions.
2. Cancel whenever possible.
3. Multiply numerators to find the numerator of the answer.
4. Multiply denominators to find the denominator of the answer.

Example: Multiply $2\frac{1}{10}$ by $\frac{5}{14}$

Option 1

Step 1 $2\frac{1}{10} = \frac{21}{10}$

Step 2 In canceling, look for a number in the numerator and the denominator that can be divided by the same number.

$$\frac{\overset{3}{21}}{10} \times \frac{5}{\underset{2}{14}} = \frac{3}{2} \times \frac{\overset{1}{5}}{\underset{2}{14}}$$

Step 3 $3 \times 1 = 3$

Step 4 $2 \times 2 = 4$

Answer $\frac{3}{4}$

Option 2

Step 1 $2\frac{1}{10} = \frac{21}{10}$

Step 2 Multiply numerators and denominators.

$$\frac{21}{10} \times \frac{5}{14} = \frac{105}{140}$$

Step 3 Reduce the result when possible.

$$\frac{105 \div 5}{140 \div 5} = \frac{21}{28} \div \frac{7}{7} = \frac{3}{4}$$

Answer $\frac{3}{4}$

In dividing fractions:

1. Change numbers to improper fractions.
2. Change the division sign to a multiplication sign and invert the divisor. The divisor is always after the division sign.
3. Follow the procedure for the multiplication of fractions.

Example: Divide $4\frac{5}{8}$ by $\frac{3}{8}$

Step 1 $4\frac{5}{8} \div \frac{3}{8}$

Step 2 $\frac{37}{8} \div \frac{3}{8} = \frac{37}{8} \times \frac{8}{3}$

Step 3 $\frac{37}{8} \times \frac{8}{3} = \frac{37 \times 8}{8 \times 3} = \frac{296}{24} = 12\frac{8}{24}$

Since 296 ÷ 24 = 12 with a remainder of 8, reduce $\frac{8}{24}$

$$\frac{8}{24} = \frac{8 \div 8}{24 \div 8} = \frac{1}{3}$$

Answer $12\frac{1}{3}$

Self-Test 1 (Answers on page 38)

1. Reduce $\frac{6}{8}$ to its lowest term.
   a. In the fraction $\frac{6}{8}$, 6 is the _____ and 8 is the _____.
   b. To reduce the fraction to its lowest terms, look for the _____ that is common to both the _____ and the _____.
   c. The largest number that can be divided into the numerator and denominator is _____.
   d. By dividing both sides by the divisor, the fraction is reduced to _____.
   e. Can the fraction be reduced any further? _____.
2. Change the fraction $\frac{4}{5}$ to the highest term $\frac{x}{40}$.
   a. To find *x* we must first find what number relates to 40. _____.
   b. 5 is what part of 40? _____.
   c. The next step is to multiply _____ by 8.
   d. *x* is _____.
   e. The fraction $\frac{4}{5}$ is expanded to _____.

Self-Test 2 (Answers on page 38)

1. Add $4\frac{1}{6}$ and $3\frac{1}{2}$.

   a. To add these mixed numbers, first find the _____ _____ of $\frac{1}{6}$ and $\frac{1}{2}$.

   b. The smallest number that 6 and 2 divide into evenly is _____. This is the common denominator.

   c. $\frac{1}{2} = \frac{x}{6}$. Find *x*.

   d. Does $\frac{1}{6}$ have to be changed to a smaller fraction? _____.

   e. Using your answer from part **c** above, $3\frac{1}{2}$ is therefore the same as 3 _____.

   f. The addition of $\frac{1}{6}$ and $\frac{1}{2}$ is _____.

   g. Are the denominators added? _____.

   h. The addition of the whole numbers is _____ .

   i. Is $7\frac{4}{6}$ the final answer? _____.

   j. What operation must be performed? _____
   _____.

   k. Simplify $\frac{4}{6}$. _____.

   l. The final answer is _____.

Self-Test 3 (Answers on page 38)

1. Multiply $\frac{3}{8}$ by 4.

   a. To multiply $\frac{3}{8}$ by 4, change _____ to a fraction.

   b. The fraction for part **a** is _____.

   c. The problem now looks like _____ × _____.

   d. Multiply the numerators; the number _____ is obtained.

   e. By multiplying the denominators, the number _____ is obtained.

   f. The fraction is now _____.

   g. $\frac{12}{8}$ reduces to _____ .

   h. Is this the final answer? _____.

   i. Why? _____.

   j. The final answer is _____ .

DECIMALS

A decimal is a fraction with a denominator that is 10, 100, 1,000, etc. The value of the decimal is shown by the place it holds to the right of the decimal point.

Example:

$$\frac{5}{10} = 0.5$$

$$\frac{5}{100} = 0.05$$

$$\frac{5}{1{,}000} = 0.005$$

$$\frac{85}{1{,}000} = 0.085$$

If there are no numbers to the left of the decimal place, a zero should be placed to the left of the decimal place. This will assist in clarifying the number.

Example: .3 = 0.3 .45 = 0.45 .689 = 0.689

When adding or subtracting decimals, put all decimals on the same vertical line.

Example: Add 0.45, 7, 0.025, and 0.05

$$\begin{array}{r} 0.450 \\ 7.000 \\ 0.025 \\ +\ 0.050 \\ \hline 7.525 \end{array}$$

To multiply decimals, find the total number of decimal places in the multiplicand and the multiplier.

$$\begin{array}{r} 0.23 \text{ (Multiplicand)} \\ \times\ 0.6 \text{ (Multiplier)} \\ \hline \text{(Product)} \end{array}$$

Counting from the right in the product, count off as many decimal places as there are in both multiplicand and multiplier. If necessary, add zeros to the left in the product.

$$0.23 \times 0.6 = 0.138$$

To change a decimal to a fraction, follow these steps:

1. For the numerator, write the figures to the right of the decimal point.
2. For the denominator, write a 1 for the decimal point and a 0 for each place.

Example: Change 0.068 to a fraction

Step 1 68

Step 2 1,000

Answer $\frac{68}{1{,}000}$

Dividing Decimals

When the divisor is a whole number and the dividend contains a decimal, place the decimal point in the quotient directly above the decimal point in the dividend.

Example: Quotient $\quad 0.00625$

Divisor $)\overline{\text{Dividend}} \quad 8\,)\overline{0.05}$

Note: Add zeros if necessary to complete the division.

Changing Fractions to Decimals

In changing a fraction to a decimal, divide the numerator by the denominator, but write the decimal point to the right of the numerator and add as many zeros as are needed to complete the division.

Example: $\frac{5}{17} = 17\,)\overline{5.0000000}\quad 0.2941176$

To divide when the divisor contains a decimal, follow these steps:

Step 1 Make sure there are as many decimal places in the dividend as there are in the divisor. If necessary, add a decimal point and zero(s) to the right of the dividend.

$3.74\,)\overline{23}$ becomes $3.74\,)\overline{23.00}$

Step 2 Make the divisor a whole number by moving the decimal point to the right of the last digit.

$374.\,)\overline{23.00}$

Step 3 Equalize this in the dividend by moving the decimal point as many places to the right as you have moved it in the divisor.

$374.\,)\overline{2300.}$

Step 4 Place the decimal point in the quotient directly above the decimal point in the dividend and divide.

$$\begin{array}{r} . \\ 374.\,)\overline{2300.} \end{array}$$

Step 5 If necessary, add more zeros to complete this division.

$$\begin{array}{r} 6.149 \\ 374.\,)\overline{2300.000} \end{array}$$

Products and Factors

A product is obtained by multiplying together two or more numbers: $8 = 4 \times 2$ (8 is the product). Each of the numbers multiplied is a factor: 4 and 2 are factors of 8. A product is divisible by each of its factors: $8 \div 4 = 2$ and $8 \div 2 = 4$. So for each multiplication, there can be two divisions:

$8 = 4 \times 2$ multiplication
$8 = ? \times 2$ division
$8 = 4 \times ?$ division
$8 = 4 \times 2$ *or* product = factor × factor

$2 = \frac{8}{4}$ *or* $4 = \frac{8}{2}$ *or* $\text{Factor} = \frac{\text{Product}}{\text{Factor}}$

One can apply these rules to three types of problems.

Type 1 Find $\frac{1}{4}$ of 24.

Product = Factor × Factor

$P = \frac{1}{4} \times 24$

P = 6

In type 1, the product is missing; therefore, the process is multiplication. 6 is the product.
Note: When one factor is less than 1, the product is less than the other factor.

Type 2 What part of 24 is 6?

Product = Factor × Factor

6 = Factor × 24

Factor = Product ÷ Factor

$\text{Factor} = \frac{6}{24}$

$\text{Factor} = \frac{1}{4}$

In type 2, one of the factors is missing; therefore, the process is division.

Type 3 If $\frac{1}{4}$ of a number is 6, what is the number? Or $6 = \frac{1}{4}$ of what number?

Product = Factor × Factor

Product = Product ÷ Factor

$\text{Product} = 6 \div \frac{1}{4} = 24$

In type 3, one of the factors is missing; therefore, the process is division.

Special Note: Calculators

As you can see, it is much easier to work with decimals than fractions. Thanks to the availability and low cost of electronic calculators, any problem involving fractions can quickly be changed to one containing decimals. This is done by simply dividing the numerator by the denominator on the calculator and adding the resulting decimal to the whole number (if any) accompanying the fraction. As an example, $5^{1}/_{17}$ can easily be converted to a decimal by first dividing 1 by 17 on the calculator. This gives a decimal of 0.059. The decimal is added to 5 to give a result of 5.059.

Calculators are useful not only in converting fractions to decimals but also to speed up any water treatment plant problem calculation. Since each type of calculator is different, familiarize yourself with the instructions for the particular calculator you will be using.

Self-Test 4 (Answers on page 38)

1. Multiply $\begin{array}{r} 0.08 \\ \times\ 1.4 \\ \hline \end{array}$

   a. Which number is the multiplicand? _____.

   b. How many decimal places are in the multiplicand? _____. In the multiplier? ____.

   c. The total number of decimal places is _____.

   d. How many places to the left of the product do you count off? _____.

   e. $0.08 \times 1.4 =$ _____.

PERCENTS

Fractions express parts of a whole. These parts may be of various sizes such as halves, thirds, fourths, fifths, tenths, hundredths, etc. Decimals express part of a whole. These parts may be tenths, hundredths, thousandths, etc. Percentages are used to express parts of a whole, but these parts are limited to hundredths. Therefore, *percent* is another name for *hundredth*. So 25% means 25 hundredths or 0.25.

Express the decimal as a percent in the following examples:

1. Move the decimal point two places to the right.

   0.02 0.20 2.00

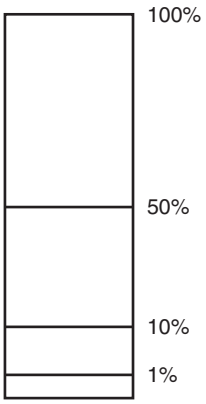
2. Annex the percent sign (%).

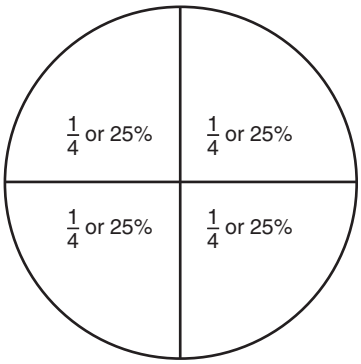
   2% 20% 200%

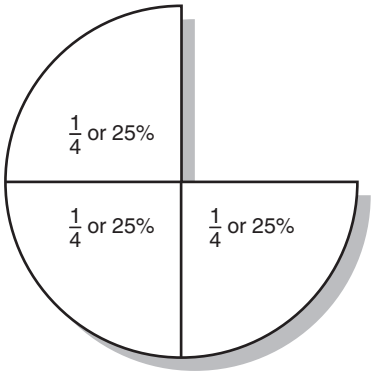
Note: Add zeros if necessary.

Study the following equivalents:

0.125	=	0.125	=	12.5%	0.03125	=	0.03125	=	3.125%
0.125	=	$0.12\frac{5}{10}$	=	$12\frac{1}{2}\%$	0.03125	=	$0.03\frac{125}{1{,}000}$	=	$3\frac{1}{8}\%$
0.0475	=	0.0475	=	4.75%	0.0125	=	0.0125	=	1.25%
0.0475	=	$0.04\frac{75}{100}$	=	$4\frac{3}{4}\%$	0.0125	=	$0.01\frac{25}{100}$	=	$1\frac{1}{4}\%$







$$100\% \quad + \quad 75\% = 175\%$$

$$\frac{4}{4} \quad + \quad \frac{3}{4} = \frac{7}{4}$$

$$100\% = 1.00 \textit{ or } 1$$

$$50\% = 0.5 \textit{ or } \frac{1}{2}$$

$$10\% = 0.1 \textit{ or } \frac{1}{10}$$

$$1\% = 0.01 \textit{ or } \frac{1}{100}$$

Percentages less than 1% are decimal or fractional percentages:

$$\frac{1}{2}\% = \frac{1}{200} \textit{ or } 0.5\% \qquad \frac{3}{4}\% = \frac{3}{400} \textit{ or } 0.75\%$$

The value of 100% is one whole or one unit. Percentages greater than 100 have a value greater than one unit. Express each decimal as a percent.

$$1.5 = 1.\underset{\hookrightarrow}{50} = 150\% \qquad 2 = 2.\underset{\hookrightarrow}{00} = 200\%$$

Expressing a Percent As a Decimal

Step 1 Drop the percent sign and add a decimal point.

$5\% = 5.0$

Step 2 Move the decimal point two places to the left.

$5.0 = 05.0 = 0.05$

Note: Prefix zeros when necessary.

Examples:

$104\% = 1.04$

$4.25\% = 0.0425$

$\frac{1}{3}\% = 0.00\frac{1}{3}$ *or* $.003\overline{3}$

$\frac{1}{2}\% = 0.00\frac{1}{2}$ *or* $.005$

Rounding Percents

$0.04518 = 4.518\%$

$= 4.52\%$ (to the nearest hundredth of a percent)

$= 4.5\%$ (to the nearest tenth of a percent

$= 5.0\%$ (to the nearest whole percent)

Changing Fractions to Percents

1. A fraction may be changed to a decimal by dividing the numerator by its denominator.
2. A decimal may be changed to a percent by moving the decimal point two places to the right and adding the percent sign.

Note how the following fraction is changed to decimals and then percents.

Example: $\frac{4}{5}$

Step 1 $5\overline{)4.0}$ (quotient 0.8)

Step 2 $0.8 = 0.80 = 80\%$

Therefore, $\frac{4}{5} = 0.8 = 80\%$

Changing Percents to Fractions

1. A percent may be changed to a decimal by dropping the percent sign and moving the decimal point two places to the left.
2. A decimal of two places may be changed to a fraction by dropping the decimal point and dividing the resulting number by 100.

Note how the following percentages are changed to decimals, then to fractions.

Example: Convert 6% to a fraction.

Step 1 $6.0 = \underbrace{06.0} = 0.06$

Step 2 $0.06 = 6 \div 100$ *or* $\frac{6}{100}$

Reducing to lowest terms, $\frac{6}{100} = \frac{3}{50}$

Therefore, $6\% = 0.06 = \frac{3}{50}$

See if you can find steps necessary to convert these percentages to decimals, then fractions.

$225\% = 2.25$

$2.25 = 2\frac{25}{100}$

$2\frac{25}{100} = 2\frac{1}{4}$

$\frac{1}{3}\% = 0.00\frac{1}{3}$

$0.00\frac{1}{3} = \frac{1}{3} \div 100 = \frac{1}{3} \times \frac{1}{100} = \frac{1}{300}$

Percents in Problems

There are three types of problems involving percentages. When solving percentage problems, be careful of where you place the decimals.

Type 1 Find what percent a number is of another number.

Determine the correct fraction and then convert to a percentage.

Example 1: What percentage of 7 is 14?

$\frac{7}{14} = \frac{1}{2} = 0.5$

$0.5 \times 100\% = 50\%$ $(0.5 = \underbrace{0.50} = 50\%)$

Example 2: 8 is what percentage of 24?

$\frac{8}{24} = 0.333$

$0.333 \times 100\% = 33.3\%$ $(0.333 = \underbrace{0.333} = 33.3\%)$

Example 3: The amount of total solids entering the first of a series of settling tanks is 150 mg/L. The amount leaving this basin and going into the second tank is 75 mg/L. What percentage of total solids is removed in the first basin?

Note: 150 – 75 is $\frac{150 - 75}{150} = \frac{75}{150} = 0.5$ of the original load.

$0.5 \times 100\% = 50\%$ removal $\quad (0.5 = 0.\underset{\uparrow}{50} = 50\%)$

Therefore, % removal = $\frac{(\text{In} - \text{Out})}{\text{In}} \times 100\%$

Type 2 Find the percentage of a given number.

The percent is expressed as a decimal and then multiplied by the other number.

Example 1: Find 8% of 36.

$0.08 \times 36 = 2.88$

Example 2: Find 75% of 12.

$0.75 \times 12 = 9$

Example 3: What is the weight of suspended solids in a ton (2,000 lb) of raw water containing 2% solids and 98% water?

Note: 2% solids means that there are 2 lb of solids for every 100 lb of water. $\left(2\% = 0.02 = \frac{2}{100}\right)$

$2{,}000 \times 0.02 = 40$ lb of suspended solids

Type 3 Find a number when a given percentage of it is known. In this type of problem, convert the percentage to a decimal and then divide by the decimal.

Example 1: If 15% of a number is 21, what is the number?

$\frac{21}{0.15} = 140$

To check the answer, find what is 15% of 140.

$0.15 \times 140 = 21$

Example 2: Percentage removal of suspended solids in a clarifier is 40%. If 85 mg/L is removed, what is the influent suspended solids?

Influent solids = $\frac{85 \text{ mg/L}}{0.40} = 212.5$ mg/L

Check: Original load × % removal = load removal

212.5 mg/L × 0.40 = 85 mg/L

RATIOS AND PROPORTIONS

When two numbers with the same units are compared, you are finding the ratio of the numbers; for example, 2 mL compared to 5 mL. Ratios can be written as fractions:

$$\frac{2}{5} \text{ or } 2{:}5 \text{ (read as } \textit{the ratio of 2 to 5}\text{)}$$

When working with ratios, you are calculating proportions. For example:

$$5{:}10 = \frac{5}{10} = \frac{1}{2}$$

The form a proportion is written in is usually

$$\frac{a}{b} = \frac{c}{d}$$

or $a{:}b = c{:}d$ (read as *a is to b as c is to d*). To solve the proportion, multiply diagonally across:

$$\frac{a}{b} \times \frac{c}{d}$$

This yields $a \times d = b \times c$. This process is called *cross multiplication*.

Example: $\frac{5}{10} = \frac{1}{2}$ $10 \times 1 = 5 \times 2$ $10 = 10$

If one complete ratio and one term of the second ratio are known, you can find the unknown term of the second ratio.

Example 1: Find c in the proportion $\frac{5}{10} = \frac{c}{2}$.

$10 \times c = 5 \times 2$

$\frac{\cancel{10} \times c}{\cancel{10}} = \frac{\cancel{5 \times 2}^{\,10}}{10}$ Divide both sides of the equation by 10.

$c = \frac{10}{10} = 1$

Example 2: If a certain machine part costs \$9.00/dozen, how much would four parts cost?

We know that 12 parts cost \$9.00; 4 parts cost x dollars. Therefore,

$\frac{12}{9.00} = \frac{4}{x}$ *or* $\frac{12}{4} = \frac{9.00}{x}$

$12 \times x = 9.00 \times 4$ *or* $12 \times x = 4 \times 9.00$

$\frac{\cancel{12} \times x}{\cancel{12}} = \frac{\cancel{9.00} \times 4^{\,36.00}}{12}$

$x = \frac{36.00}{12}$ Reduce.

$x = 3.00$

$x =$ \$3.00 per 4 parts

Example 3: If 5 lb of a chemical are added to 25 gal of water to make a solution of a given strength, how many pounds would have to be added to 121 gal to give the same concentration?

$$x = \text{lb of chemical}$$

$$\frac{5\text{ lb}}{25\text{ gal}} = \frac{x}{121\text{ gal}}$$

$$(x)(25\text{ gal}) = (5\text{ lb})(121\text{ gal})$$

$$\frac{(x)(\cancel{25\text{ gal}})}{\cancel{25\text{ gal}}} = \frac{605\ \cancel{\text{gal}}\ \text{lb}}{25\ \cancel{\text{gal}}}$$

$$x = \frac{605\text{ lb}}{25}$$

$$x = \frac{121\text{ lb}}{5}$$

$$x = 24.2\text{ lb}$$

Note: Gallons in the numerator and denominator are canceled just like numbers of the same value (i.e., 25/25 = 1).

Example 4: If four workers do a job in 9 h, how long will it take six workers to do the same job?

$$x = \text{hours to complete job}$$

$$\frac{4\text{ workers}}{9\text{ h}} = \frac{6\text{ workers}}{x\text{ h}}$$

$$(4\text{ workers})(x) = (6\text{ workers})(9\text{ h})$$

$$\frac{(\cancel{4\text{ workers}})(x)}{\cancel{4\text{ workers}}} = \frac{(6\ \cancel{\text{workers}})(9\text{ h})}{4\ \cancel{\text{workers}}} \quad 54\text{ h}$$

$$x = \frac{54\text{ h}}{4}$$

$$x = \frac{27\text{ h}}{2}$$

$$x = 13.5\text{ h}$$

Is this answer correct? Can it take more workers more time to do the same job? In most cases, the answer is no. This is an example of ratios that are inversely proportional to each other. In this case, the products are constant, not their ratios. The proper way to solve this problem is as follows:

$$x = \text{hours to complete job}$$

$$(4\text{ workers})(9\text{ h}) = (6\text{ workers})(x)$$

$$\frac{(36\ \cancel{\text{workers}})(\text{h})}{6\ \cancel{\text{workers}}} = \frac{(\cancel{6\text{ workers}})(x)}{\cancel{6\text{ workers}}}$$

$$\frac{36\text{ h}}{6} = x$$

$$6\text{ h} = x$$

PRACTICE PROBLEMS (Answers on page 33)

Fractions

Reduce to lowest terms

1. $\frac{21}{49} =$ $\frac{24}{28} =$ $\frac{56}{64} =$
2. $\frac{63}{81} =$ $\frac{14}{42} =$ $\frac{30}{45} =$
3. $\frac{27}{81} =$ $\frac{24}{72} =$ $\frac{24}{38} =$
4. $\frac{72}{96} =$ $\frac{48}{72} =$ $\frac{19}{38} =$

Change to higher terms

1. $\frac{7}{9} = \frac{\quad}{54}$ $\frac{6}{7} = \frac{\quad}{56}$ $\frac{9}{10} = \frac{\quad}{50}$
2. $\frac{5}{6} = \frac{\quad}{48}$ $\frac{7}{15} = \frac{\quad}{60}$ $\frac{3}{20} = \frac{\quad}{80}$
3. $\frac{1}{6} = \frac{\quad}{18}$ $\frac{1}{6} = \frac{\quad}{54}$
4. $\frac{4}{5} = \frac{\quad}{60}$ $\frac{4}{5} = \frac{\quad}{35}$

Change to a whole or mixed number

1. $\frac{19}{9} =$ $\frac{54}{9} =$ $\frac{35}{8} =$
2. $\frac{58}{6} =$ $\frac{76}{8} =$ $\frac{50}{9} =$
3. $\frac{32}{8} =$ $\frac{42}{5} =$ $\frac{81}{9} =$
4. $\frac{59}{7} =$ $\frac{76}{9} =$ $\frac{44}{7} =$

Change to improper fractions

1. $4\frac{3}{5} =$ $9\frac{1}{8} =$ $5\frac{3}{10} =$
2. $6\frac{7}{8} =$ $4\frac{7}{11} =$ $2\frac{9}{13} =$
3. $1\frac{1}{25} =$ $8\frac{4}{7} =$ $2\frac{5}{12} =$

Change the whole number to an improper fraction

1. $3 = \frac{}{4}$ $4 = \frac{}{5}$ $5 = \frac{}{9}$
2. $4 = \frac{}{4}$ $9 = \frac{}{6}$ $5 = \frac{}{10}$
3. $12 = \frac{}{2}$ $2 = \frac{}{24}$ $10 = \frac{}{12}$

Change to simplest form

1. $7\frac{10}{10} =$ $8\frac{9}{9} =$ $5\frac{24}{24} =$
2. $8\frac{10}{9} =$ $5\frac{7}{6} =$ $9\frac{9}{7} =$
3. $7\frac{16}{12} =$ $2\frac{24}{18} =$ $6\frac{40}{32} =$
4. $3\frac{4}{5} =$ $4\frac{15}{12} =$ $8\frac{35}{40} =$
5. $7\frac{27}{24} =$ $9\frac{15}{15} =$ $3\frac{25}{20} =$

Addition and subtraction of fractions

Add:

1. $\frac{1}{8} + \frac{5}{8}$ $\frac{7}{8} + \frac{3}{8}$ $\frac{5}{6} + \frac{1}{6}$
2. $7\frac{1}{4} + 8\frac{3}{4}$ $9\frac{2}{5} + 6\frac{3}{5}$
3. $10\frac{3}{4} + 5\frac{3}{4}$ $7\frac{13}{24} + 8\frac{17}{24}$

4. $7\frac{3}{5} + \frac{4}{5}$ $\frac{8}{9} + 4\frac{7}{9}$

5. $6\frac{3}{4} + 9\frac{5}{8}$ $7\frac{5}{12} + 8\frac{5}{6}$

6. $5\frac{5}{6} + 6\frac{2}{3} + 3\frac{7}{12}$ $6\frac{1}{2} + 10\frac{5}{8} + \frac{3}{4}$

7. $\frac{7}{8} + \frac{1}{6}$ $\frac{5}{6} + \frac{7}{9}$

8. $6\frac{4}{9} + 10\frac{5}{12} + 18\frac{1}{6} + 14\frac{5}{8} + 5\frac{1}{4}$

9. $9\frac{1}{2} + 6\frac{3}{4} + 3\frac{7}{8} + 14\frac{5}{6} + 8\frac{2}{3}$

Subtract:

1. $\frac{4}{9} - \frac{1}{3}$ $\frac{7}{12} - \frac{1}{6}$ $\frac{11}{24} - \frac{3}{8}$

2. $\frac{5}{9} - \frac{1}{6}$ $\frac{9}{10} - \frac{4}{15}$ $\frac{11}{24} - \frac{3}{16}$

3. $2\frac{1}{2} - 1\frac{1}{4}$ $9\frac{7}{24} - 3\frac{1}{8}$ $8\frac{7}{24} - 6\frac{1}{6}$

4. $8\frac{1}{3} - \frac{3}{5}$ $7 - 1\frac{4}{7}$ $6\frac{1}{10} - \frac{9}{10}$

5. $8\frac{1}{6} - 6\frac{5}{9}$ $4\frac{3}{5} - 3\frac{6}{7}$

6. From $9\frac{5}{8}$ take $7\frac{1}{3}$ Take $2\frac{4}{9}$ from $7\frac{1}{4}$

7. From $3\frac{2}{9}$ take $1\frac{7}{12}$ Take $2\frac{5}{6}$ from $8\frac{1}{4}$

Find the answers:

1. $\frac{1}{2}+\frac{5}{12}-\frac{2}{3}$ $\frac{8}{9}-\frac{1}{3}+\frac{4}{9}$

2. $\frac{7}{9}+\frac{2}{3}+\frac{9}{10}$ $\frac{3}{4}-\frac{3}{8}+\frac{1}{2}$

3. $\frac{2}{3}-\frac{5}{12}+\frac{3}{20}$ $\frac{3}{5}+\frac{3}{20}-\frac{1}{4}$

4. From the sum of $\frac{3}{4}$ and $\frac{1}{6}$ take away $\frac{5}{8}$.

5. From 8 take the difference between $4\frac{5}{18}$ and $2\frac{7}{12}$.

Multiplication and division of fractions

Multiply:

1. $\frac{5}{9}\times 27 =$ $\frac{9}{10}\times 15 =$ $\frac{3}{8}\times 32 =$

2. $\frac{4}{15}\times 9 =$ $12\times\frac{7}{8} =$ $10\times\frac{5}{8} =$

3. $6\times\frac{5}{12} =$ $12\times\frac{5}{24} =$ $27\times\frac{4}{21} =$

4. $\frac{5}{6}\times\frac{3}{10} =$ $\frac{9}{10}\times\frac{5}{12} =$ $\frac{24}{25}\times\frac{5}{8} =$

5. $3\frac{1}{9}\times\frac{6}{7} =$ $6\frac{2}{9}\times\frac{3}{8} =$ $\frac{20}{21}\times 2\frac{4}{7} =$

6. $12\times\frac{3}{8} =$ $3\times\frac{5}{12} =$ $\frac{4}{5}\times 35 =$

7. $6\frac{1}{4}\times 1\frac{1}{10}\times 7\frac{1}{2}\times 3\frac{1}{9} =$

8. $5\frac{1}{3}\times 3\frac{3}{4}\times\frac{7}{12}\times 2\frac{5}{5} =$

9. $6\frac{2}{5}\times 15\frac{7}{8}\times 2\frac{5}{6} =$

10. $\frac{14}{15}\times 2\frac{1}{24}\times 5\frac{5}{7}\times 1 =$

Divide:

1. $1\frac{1}{5} \div \frac{3}{4} =$ $5\frac{4}{7} \div \frac{3}{14} =$ $8\frac{1}{6} \div \frac{7}{14} =$

2. $\frac{4}{9} \div \frac{7}{15} =$ $\frac{5}{6} \div \frac{7}{8} =$ $\frac{14}{15} \div \frac{14}{15} =$

3. $6 \div \frac{2}{3} =$ $\frac{5}{8} \div 10 =$ $\frac{32}{32} \div 16 =$

4. $6\frac{1}{2} \div 2\frac{5}{8} =$ $8\frac{1}{3} \div 7\frac{1}{7} =$ $5\frac{4}{9} \div 3\frac{1}{3} =$

5. $\frac{9}{10} \times \frac{8}{9} \div \frac{7}{30} =$ $3\frac{1}{5} \times \frac{7}{12} \div 2\frac{1}{3} =$

6. $10 \div \frac{5}{6} =$ $9 \div \frac{3}{8} =$ $35 \div \frac{7}{10} =$

7. $\frac{5}{9} \div 15 =$ $\frac{9}{10} \div 6 =$ $\frac{7}{12} \div 14 =$

8. $\frac{3}{4} \div \frac{9}{8} =$ $\frac{9}{14} \div \frac{6}{7} =$ $\frac{21}{28} \div \frac{3}{7} =$

Decimals

Add and subtract:

1. 0.4 + 2.05 + 1.6 + 0.403 =

2. 3.57 + 35.7 + 0.357 + 0.0357 =

3. 5.942 + 87.04 + 0.367 + 0.451 =

4. From 8.1 take 4.073

5. Take 0.405 from 0.45

6. What is the difference between 0.09 and 0.07?

Multiply:

1. 0.014×0.8 $\quad$ 1.4×0.08 $\quad$ 8.6×0.35

2. 34.8×0.92 $\quad$ 628.3×0.35 $\quad$ 83.62×9.2

3. 9.035×0.84 $\quad$ 5.391×3.8 $\quad$ 0.8927×70

4. 0.0009 by 900 = $\quad$ 135.47 by 702 =

5. 700.05 by 405 = $\quad$ 9,700 by 5.04 =

Express as fractions in their lowest terms:

1. 0.125 = $\quad$ 0.0075 = $\quad$ 0.625 =

2. 0.0625 = $\quad$ 0.375 = $\quad$ 0.0375 =

3. 0.955 = $\quad$ 0.0875 = $\quad$ 0.0065 =

Divide:

1. $9\overline{)0.27}$ $\quad$ $7\overline{)0.42}$ $\quad$ $4\overline{)0.05}$

2. $32\overline{)0.12}$ $\quad$ $24\overline{)93.2}$ $\quad$ $75\overline{)25.5}$

3. $24\overline{)17.28}$ $\quad$ $56\overline{)45.08}$ $\quad$ $72\overline{)0.252}$

4. $.08\overline{)64}$ $\quad$ $0.7\overline{)42}$ $\quad$ $0.06\overline{)192}$

5. $0.04\overline{)35}$ $\quad$ $0.08\overline{)3}$ $\quad$ $0.16\overline{)1}$

6. $6.4\overline{)48}$ $13.2\overline{)198}$ $0.04\overline{)3.4}$

7. $0.018\overline{)10.8}$ $0.06\overline{)0.288}$ $0.16\overline{)4.8}$

8. $0.23\overline{)3.381}$ $0.24\overline{)1.632}$ $0.48\overline{)1.2}$

9. $0.25\overline{)78.8}$ $2.7\overline{)4.374}$ $0.07\overline{)1.9684}$

Change to decimals:

1. $\frac{1}{8}$ = $\frac{1}{20}$ = $\frac{4}{5}$ = $\frac{3}{4}$ = $\frac{19}{20}$ = $\frac{12}{25}$ =

Solve the following problems:

1. What is $\frac{4}{5}$ of 24?
2. What is $\frac{5}{9}$ of 72?
3. Find 0.875 of 56.
4. How many times 12 is 27?
5. At 260 mph, how far will a plane travel in $3\frac{1}{2}$ h?
6. If a pilot averages 320 mph, how long will it take to go 1,440 mi?

Percents

Express as percentages:

1. 0.0625 = 0.0875 = 0.01125 =
2. 0.06375 = 0.04875 = 0.0275 =
3. 0.065 = 0.051 = 0.009 =
4. 3.25 = 1.42 = 5.04 =
5. 4.05 = 3.09 = 6 =

Express as decimals:

1.	12% =	62.5% =	$66\frac{2}{3}\%$ =
2.	$66\frac{2}{3}\%$ =	$14\frac{2}{7}\%$ =	37.5% =
3.	3.75% =	12.5% =	$3\frac{1}{3}\%$ =
4.	106% =	$\frac{1}{3}\%$ =	0.5% =
5.	115% =	$\frac{1}{6}\%$ =	160% =

Missing Dimensions

	Perimeter	Length	Width
1.	_____ ft	12 ft	11 ft
2.	_____ ft	24 ft	19 ft
3.	_____ ft	3 ft 8 in.	$12\frac{1}{2}$ ft
4.	_____ ft	$1\frac{2}{3}$ yd	$1\frac{1}{6}$ ft
5.	42 ft	_____ ft	5 ft
6.	6 yd	6 ft	_____ ft
7.	17 ft	_____ ft	$1\frac{1}{16}$ ft
8.	100 ft	27 ft	_____ ft

9. How many feet of molding will be needed to go around a room 12 ft wide by 5 yd long?
10. How many feet are there in a perimeter of a rectangular lot 97 ft 6 in. deep with a frontage of $9\frac{1}{2}$ yd?

ANSWERS TO PRACTICE PROBLEMS

Fractions

Reduce to lowest terms

1.	$\frac{3}{7}$	$\frac{6}{7}$	$\frac{7}{8}$
2.	$\frac{7}{9}$	$\frac{1}{3}$	$\frac{2}{3}$
3.	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{12}{19}$
4.	$\frac{3}{4}$	$\frac{2}{3}$	$\frac{1}{2}$

Change to higher terms

1.	42	48	45
2.	40	28	12
3.	3	9	
4.	48	28	

Change to a whole or mixed number

1.	$2\frac{1}{9}$	6	$4\frac{3}{8}$
2.	$9\frac{2}{3}$	$9\frac{1}{2}$	$5\frac{5}{9}$
3.	4	$8\frac{2}{5}$	9
4.	$8\frac{3}{7}$	$8\frac{4}{9}$	$6\frac{2}{7}$

Change to improper fractions

1.	$\frac{23}{5}$	$\frac{73}{8}$	$\frac{53}{10}$
2.	$\frac{55}{8}$	$\frac{51}{11}$	$\frac{35}{13}$
3.	$\frac{26}{25}$	$\frac{60}{7}$	$\frac{29}{12}$

Change the whole number to an improper fraction

1.	$\frac{12}{4}$	$\frac{20}{5}$	$\frac{45}{9}$
2.	$\frac{16}{4}$	$\frac{54}{6}$	$\frac{50}{10}$
3.	$\frac{24}{2}$	$\frac{48}{24}$	$\frac{120}{12}$

Change to simplest form

1. 8 9 6
2. $9\frac{1}{9}$ $6\frac{1}{6}$ $10\frac{2}{7}$
3. $8\frac{1}{3}$ $3\frac{1}{3}$ $7\frac{1}{4}$
4. $3\frac{4}{5}$ $5\frac{1}{4}$ $8\frac{7}{8}$
5. $8\frac{1}{8}$ 10 $4\frac{1}{4}$

Addition and subtraction of fractions

Add:

1. $\frac{6}{8} = \frac{3}{4}$ $\frac{10}{8} = \frac{5}{4} = 1\frac{1}{4}$ $\frac{6}{6} = 1$
2. 16 16
3. $16\frac{1}{2}$ $16\frac{1}{4}$
4. $8\frac{2}{5}$ $5\frac{2}{3}$
5. $16\frac{3}{8}$ $16\frac{1}{4}$
6. $16\frac{1}{12}$ $17\frac{7}{8}$
7. $1\frac{1}{24}$ $1\frac{11}{18}$
8. $54\frac{65}{72}$
9. $43\frac{5}{8}$

Subtract:

1. $\frac{1}{9}$ $\frac{5}{12}$ $\frac{2}{24} = \frac{1}{12}$
2. $\frac{7}{18}$ $\frac{19}{30}$ $\frac{13}{48}$
3. $1\frac{1}{4}$ $6\frac{1}{6}$ $2\frac{1}{8}$
4. $7\frac{11}{15}$ $5\frac{3}{7}$ $5\frac{1}{5}$
5. $1\frac{11}{18}$ $\frac{26}{35}$
6. $2\frac{7}{24}$ $4\frac{29}{36}$
7. $1\frac{23}{36}$ $5\frac{5}{12}$

Find the answers:

1. $\frac{1}{4}$ 1
2. $2\frac{31}{90}$ $\frac{7}{8}$
3. $\frac{2}{5}$ $\frac{1}{2}$
4. $\frac{7}{24}$
5. $6\frac{11}{36}$

Multiplication and division of fractions
Multiply:

1. 15 $13\frac{1}{2}$ 12
2. $2\frac{2}{5}$ $10\frac{1}{2}$ $6\frac{1}{4}$
3. $2\frac{1}{2}$ $2\frac{1}{2}$ $5\frac{1}{7}$
4. $\frac{1}{4}$ $\frac{3}{8}$ $\frac{3}{5}$
5. $2\frac{2}{3}$ $2\frac{1}{3}$ $2\frac{22}{49}$
6. $4\frac{1}{2}$ $1\frac{1}{4}$ 28
7. $160\frac{5}{12}$
8. 35
9. $287\frac{13}{15}$
10. $10\frac{8}{9}$

Divide:

1.	$\frac{8}{5} = 1\frac{3}{5}$	26	14
2.	$\frac{20}{21}$	$\frac{20}{21}$	1
3.	9	$\frac{1}{16}$	$\frac{1}{16}$
4.	$\frac{52}{21} = 2\frac{10}{21}$	$\frac{7}{6} = 1\frac{1}{6}$	$\frac{49}{30} = 1\frac{19}{30}$
5.	$\frac{24}{7} = 3\frac{3}{7}$	$\frac{4}{5}$	
6.	12	24	50
7.	$\frac{1}{27}$	$\frac{3}{20}$	$\frac{1}{24}$
8.	$\frac{2}{3}$	$\frac{3}{4}$	$\frac{7}{4} = 1\frac{3}{4}$

Decimals

Add and subtract:

1.	4.453	4.	4.027
2.	39.6627	5.	0.045
3.	93.8	6.	0.02

Multiply:

1.	0.0112	0.112	3.010
2.	32.016	219.905	769.304
3.	7.58940	20.4858	62.4890
4.	0.81	95,099.94	
5.	283,520.25	48,888.00	

Express as fractions in their lowest terms:

1.	$\frac{1}{8}$	$\frac{3}{400}$	$\frac{5}{8}$
2.	$\frac{1}{16}$	$\frac{3}{8}$	$\frac{3}{80}$
3.	$\frac{191}{200}$	$\frac{7}{80}$	$\frac{13}{2{,}000}$

Divide:

1.	0.03	0.06	0.0125
2.	0.00375	3.88	0.34
3.	0.72	0.805	0.0035
4.	800	60	3,200
5.	875	37.5	6.25
6.	7.5	15	85
7.	600	4.8	30
8.	14.7	6.8	2.5
9.	315.2	1.62	28.12

Change to decimals:

1. 0.125 0.05 0.80 0.75 0.95 0.48

Solve the following problems:

1. $19\frac{1}{5}$
2. 40
3. 49
4. $2\frac{1}{4}$
5. 910 mi
6. $4\frac{1}{2}$ h

Percents

Express as percentages:

1.	6.25%	8.75%	1.125%
2.	6.375%	4.875%	2.75%
3.	6.5%	5.1%	0.9%
4.	325%	142%	504%
5.	405%	309%	600%

Express as decimals:

1.	0.12	0.625	0.666
2.	0.6667	0.1428	0.375
3.	0.0375	0.125	0.033
4.	1.06	0.0033	0.005
5.	1.15	0.001667	1.60

Missing Dimensions

1. 46 ft
2. 86 ft
3. $32\frac{1}{3}$ ft
4. $12\frac{1}{3}$ ft
5. 16 ft
6. 3 ft
7. $7\frac{7}{16}$ ft
8. 23 ft
9. 54 ft
10. 252 ft

ANSWERS TO SELF-TESTS

Answers to Self-Test 1

1a. numerator, denominator

1b. divisor, numerator, denominator

1c. 2

1d. $\frac{3}{4}$

1e. No

2a. 5

2b. 8

2c. 4

2d. 32

2e. $\frac{32}{40}$

Answers to Self-Test 2

1a. common denominator

1b. 6

1c. 3

1d. No

1e. $\frac{3}{6}$

1f. $\frac{4}{6}$

1g. No

1h. 7

1i. No

1j. Reduce $\frac{4}{6}$ to its lowest term.

1k. $\frac{4 \div 2}{6 \div 2} = \frac{2}{3}$

1l. $7\frac{2}{3}$

Answers to Self-Test 3

1a. 4

1b. $\frac{4}{1}$

1c. $\frac{3}{8} \times \frac{4}{1}$

1d. 12

1e. 8

1f. $\frac{12}{8}$

1g. $\frac{12 \div 4}{8 \div 4} = \frac{3}{2} =$

1h. No

1i. The answer needs to be written as a mixed number.

1j. $1\frac{1}{2}$

Answers to Self-Test 4

1a. 0.08

1b. two, one

1c. 3

1d. 3

1e. 0.112

Powers and Scientific Notation

OBJECTIVES

After completing a study of this chapter, you should understand:

- how to convert numbers and units from exponential form to whole numbers or expanded form
- how to change numbers and units from the expanded form into the exponential form
- how to take numbers out of positive and negative scientific notation
- how to put numbers into scientific notation

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 1, Powers and Scientific Notation.

OTHER ASSIGNMENTS

CLASS NOTES

1. Powers notation:

2. Scientific notation (10 to the *n*th power):

REVIEW QUESTIONS

1. How is the term cm^2 written in expanded form?

2. How is the term 20^3 written in expanded form?

3. How is the term $\left(\frac{4}{5}\right)^2$ written in expanded form?

4. Write the term 10^{-3} in expanded form.

5. How would the following terms be written in exponential form?

   a. (ft)(ft)

   b. (2)(2)(2)(2)

   c. $\frac{(\text{in.})(\text{in.})}{\text{min}}$

   d. $\frac{1}{(10)(10)(10)}$

   e. $\frac{(\text{ft})(\text{ft})(\text{ft})}{\text{min}}$

   f. $\frac{(\text{ft})(\text{ft})}{\text{s}}$

6. Take the following numbers out of scientific notation:

   a. 1.921×10^{2}

   b. 4.7×10^{-3}

   c. 7.889×10^{6}

   d. 2.76×10^{-1}

7. Put the following numbers into scientific notation:

   a. 7,960

   b. 0.0875

   c. 30

   d. 0.00042

ADDITIONAL NOTES

Dimensional Analysis

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of expressing a horizontal fraction as a vertical fraction
- how to divide by a fraction
- how to divide out or cancel terms in the numerator and denominator of a fraction

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 2, Dimensional Analysis.

OTHER ASSIGNMENTS

CLASS NOTES

1. Using horizontal and vertical fractions:

2. Dividing by a fraction:

3. Canceling terms in a fraction:

4. Examples:

REVIEW QUESTIONS

1. Suppose you have the terms 2,500,000 L/d and 1,440 min/d. If you wish to obtain liters per minute, would the following math setup be correct? Explain your answer.

$$\frac{2{,}500{,}000\ \text{L/d}}{1{,}440\ \text{min/d}}$$

2. Suppose you had set up the following equation. If you wanted to obtain square yards, would this setup be correct? Explain your answer.

$$(500\ \text{in.}^2)(144\ \text{in.}^2/\text{ft}^2)(3\ \text{yd}^2/\text{ft}^2)$$

3. If you wish to obtain an answer in pounds, is the following setup correct? Explain your answer.

$$\frac{(20{,}000\ \text{ft}^3)(7.48\ \text{gal/ft}^3)}{8.34\ \text{lb/gal}}$$

4. Solve the following problems:

   a. $(\text{ft})(\text{ft})(\text{ft}) =$

   b. $\dfrac{(\text{ft})(\text{ft})(\text{ft})}{\text{s}} =$

   c. $(\text{mgd})\left(\dfrac{\text{gal}}{\text{MG}}\right)\left(\dfrac{\text{min}}{\text{d}}\right) =$

   d. $(\text{gpm})\left(\dfrac{\text{min}}{\text{s}}\right) =$

   e. $\left(\dfrac{\text{ft}^3}{\text{s}}\right)\left(\dfrac{\text{gal}}{\text{ft}^3}\right)\left(\dfrac{\text{s}}{\text{min}}\right) =$

   f. $\dfrac{\text{gpm}}{\text{ft}^2} =$

   g. $\dfrac{(\text{ft}^3)\left(\dfrac{\text{gal}}{\text{ft}^3}\right)}{\text{gpm}} =$

h. $(\text{in.})\left(\frac{\text{ft}}{\text{in.}}\right)(\text{ft})(\text{ft})\left(\frac{\text{gal}}{\text{ft}^3}\right) =$

i. $(\text{ft})^2(\text{ft})\left(\frac{\text{gal}}{\text{ft}^3}\right) =$

j. $(\text{mg/L})\left(\frac{\text{gpg}}{\text{mg/L}}\right)(\text{gal}) =$

k. $\left(\frac{\text{lb}}{\text{month}}\right)\left(\frac{\text{month}}{\text{d}}\right) =$

l. $(\text{ft}^3)\left(\frac{\text{grains}}{\text{ft}^3}\right) =$

m. $\frac{\text{grains}}{(\text{mg/L})\left(\frac{\text{gpg}}{\text{mg/L}}\right)} =$

n. $(\text{hp})\left(\frac{\text{watts}}{\text{hp}}\right) =$

o. $\frac{\text{gal}}{\left(\frac{\text{gal}}{\text{ft}^3}\right)\left(\frac{\text{s}}{\text{day}}\right)} =$

p. $\frac{(\text{N})(\text{mL})}{\text{mL}} =$

q. $(\text{ppb})(\text{mgd})\left(\frac{\text{lb}}{\text{gal}}\right) =$

r. $(\text{mg/L})(\text{mgd})\left(\frac{\text{lb}}{\text{gal}}\right) =$

ADDITIONAL NOTES

Rounding and Estimating

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of rounding off complex numbers to a particular place value in the decimal system
- how to estimate the approximate size of a calculation

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 3, Rounding and Estimating.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definitions:

2. Rounding:

3. Estimating:

4. Using scientific notation in estimating:

REVIEW QUESTIONS

1. Round 498,270 to the nearest thousand.

2. Round 2,255 to the nearest hundred.

3. Round 338.23 to the nearest tenth.

4. Several calculations were rounded for estimating purposes. What are the estimated answers to the problems shown here?

   a. (70)(300)

   b. (90)(40)

   c. $\frac{60{,}000}{800}$

   d. $\frac{200}{70{,}000}$

   e. $\frac{(30)(50)(600)}{(90)(20)}$

   f. $\frac{(70{,}000)(200)}{(40)(90)(20)}$

5. Estimate the answers to the following calculations:

   a. $\frac{(16)(25)}{290}$

   b. (0.785)(90)(90)

   c. $\frac{(730)(55)}{(42)(7.48)}$

6. Estimate the answers to the following calculations:

   a. $\frac{(6.93)(3.215)(15)}{(0.785)(34)(34)}$

   b. $\frac{(16.7)(790)(0.0093)}{(0.037)(57)}$

ADDITIONAL NOTES

Solving for the Unknown Value

OBJECTIVES

After completing study of this chapter, you should understand:

- methods for solving for the unknown value in an equation using multiplication and division
- how to solve for the unknown value in an equation using addition and subtraction

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 4, Solving for the Unknown Value.

OTHER ASSIGNMENTS

CLASS NOTES

1. Applications in water supply operations:

2. Equations using multiplication and division:

3. Equations using addition and subtraction:

REVIEW QUESTIONS

In the following problems, solve for the unknown value. Rearrange the terms (if necessary), but do *not* complete the arithmetic once the unknown has been solved for.

1. $20{,}176 = (15)(20)(x)(7.48)$

2. $\frac{x}{136} = 1.5$

3. $\frac{1{,}200{,}000}{x} = 1.7$

4. $(0.785)(x^2) = 176.625$

5. $2.3 = \frac{(0.785)(x^2)(14)(7.48)}{(0.785)(60)(60)}$

6. $8.3 = x + 0.6$

7. $106 + 48 - x = 148$

8. $2{,}807 = \frac{x}{(0.785)(40)(40)}$

9. $0.58 = \frac{(160)(3.4)(8.34)}{(1{,}860)(x)(8.34)}$

10. $87.35 = \frac{84{,}000}{(0.785)(x^2)}$

11. $10.6 - x = 8.4$

12. $0.048 = \frac{2{,}090 + 493}{x + 25{,}327}$

ADDITIONAL NOTES

Ratios and Proportions

OBJECTIVES

After completing study of this chapter, you should understand:

- how ratios and proportions are used
- applications of ratios and proportions in water system calculations
- how to perform ratio and proportion calculations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 5, Ratios and Proportions.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definitions:

2. Practical applications:

REVIEW QUESTIONS

1. Are 4/7 and 51/91 proportionate?

2. Are 108/120 and 4/5 proportionate?

3. Given the following proportion, what is the value of the unknown number?

$$\frac{7.2}{20} = \frac{x}{31}$$

4. Solve for the unknown value in the following proportion:

$$\frac{x}{14} = \frac{18}{90}$$

5. If 42 lb of chemical cost $12.20, how much will 150 lb cost?

6. A man working 8 hours each day requires 15 days to complete a job. How many days will be required to complete the job if he works 9 hours each day?

7. A pump making 32 strokes per minute discharges 600 gpm (gallons per minute) of water. If the speed is increased to 35 strokes per minute, what will the discharge be in gallons per minute?

8. Suppose it takes 30 L of paint to cover 700 m^2 of a tank. How many liters of paint would be required to cover 1,150 m^2 of tank?

9. If a 4-gpm pump will fill a tank in 21 hours, what size pump would be required to complete the same job in 12 hours?

ADDITIONAL NOTES

Averages

OBJECTIVES

After completing study of this chapter, you should understand:

- how to calculate averages of groups of numbers
- common applications of averaging in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 6, Averages.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definition of the term *average*:

2. Arithmetic mean calculation:

3. Examples:

REVIEW QUESTIONS

1. The finished water turbidity readings for 2 consecutive days at a treatment plant were 0.9 TU (turbidity units) and 0.6 TU. What was the average turbidity for that 2-day period?

2. The following amounts of alum were used in a treatment plant each month for a year. What was the average monthly requirement of alum (in kilograms)?

Month	Alum (kg)	Month	Alum (kg)
January	4,640	July	4,810
February	4,580	August	4,830
March	4,550	September	4,760
April	4,500	October	4,660
May	4,610	November	4,610
June	4,650	December	4,630

3. Given the following hourly flow rates, determine the average hourly flow rate for the 24-hour period.

Time	mgd	Time	mgd
12 midnight	0.32	12 noon	1.30
1 a.m.	0.28	1 p.m.	1.25
2 a.m.	0.22	2 p.m.	1.22
3 a.m.	0.21	3 p.m.	1.23
4 a.m.	0.27	4 p.m.	1.28
5 a.m.	0.38	5 p.m.	1.37
6 a.m.	0.55	6 p.m.	1.50
7 a.m.	1.00	7 p.m.	1.69
8 a.m.	1.18	8 p.m.	1.75
9 a.m.	1.31	9 p.m.	1.67
10 a.m.	1.33	10 p.m.	0.95
11 a.m.	1.33	11 p.m.	0.50

ADDITIONAL NOTES

Percent

OBJECTIVES

After completing study of this chapter, you should understand:

- how to perform percent calculations
- common uses of percent applications in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 7, Percent.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definition of the term *percentage*:

2. Relationship between percents, fractions, and decimals numbers:

3. General rule on moving the decimal point:

4. Formula for percent problems:

5. Solving for unknowns in percent problems:

6. Percentages greater than 100:

REVIEW QUESTIONS

1. Express the following decimal numbers as percents:
   a. 0.25
   b. 0.68
   c. 0.035
   d. 0.0005
   e. 1.20
2. Express the following percents as decimals:
   a. 15%
   b. 74%
   c. 3%
   d. 0.4%
   e. 110%
3. What percent is 1,260 of 3,000?

4. What is 21 percent of 247?

5. The number 242 is 40 percent of what other number?

6. If 20 percent of a certain number is 35, what is the number?

7. The capacity of a treatment plant is 5 ML/d (megaliters per day). If the flow at the treatment plant is 3.3 ML/d, the plant is operating at what percent of its capacity?

8. From a stock of 200 machines, 82 percent are in use. How many machines are in use?

9. If there are 100 ft^3 of water in a tank and the tank is capable of holding 1,000 gal, the tank is filled to what percent of its capacity?

10. In 1995, the average daily flow at a treatment plant was 8.5 mgd (million gallons per day). On July 22, 1995, the plant experienced its peak day, with a flow of 20 mil gal. This peak-day flow represents what percent of the average daily flow?

ADDITIONAL NOTES

Linear Measurements

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of performing linear measurements of angular and circular objects
- common applications of linear measurements in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 8, Linear Measurements.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definitions:

2. Perimeter of angular shapes:

3. Circumference of a circle:

4. Diameter of a circle:

5. Relationship between circumference and diameter:

REVIEW QUESTIONS

1. A rectangular tank is 20 m wide and 90 m long. What is the perimeter of this tank?

2. A fence is going to be put around a circular area. If the diameter of the circular area is 30 ft, how many feet of fencing material will be required?

3. A circular tank has a circumference of 78.5 ft. What is the diameter of this tank?

4. The lengths of each side of a fenced area are as follows: 50 ft, 75 ft, 37 ft, and 84 ft. What is the perimeter of the fenced area?

5. The length of one side of a rectangular aeration basin is 75 ft. If the perimeter is 200 ft, what are the lengths of the other three sides (*three separate answers*)?

6. The weir diameter of a clarifier is 25 ft. What is the total measurement in feet of weir for the clarifier?

ADDITIONAL NOTES

Area Measurements

OBJECTIVES

After completing study of this chapter, you should understand:

- how to compute area measurements of rectangles, triangles, and circles
- common applications of area measurements in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 9, Area Measurements.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definition of the term *area*:

2. Area of a rectangle:

3. Area of a triangle:

4. Area of a circle:

REVIEW QUESTIONS

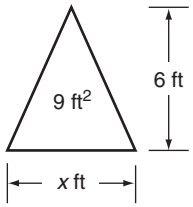
1. The top dimensions of a tank are 12 ft by 20 ft. What is the area of the water surface in the tank?

2. A piece of land that measures 1,000 ft by 2,500 ft and is adjacent to the treatment plant is being reserved for future plant expansion. How many acres is this?

3. What is the area of a triangle that has a base of 50 m and a height of 32 m?

4. The bottom of a cylindrical basin has to be painted. If the basin has a diameter of 30 ft, how many square feet must be painted?

5. Solve for x.



6. The weir diameter of a clarifier is 35 ft. What is the total feet of weir for the clarifier?

7. The rapid sand filters at a treatment plant measure 15 ft wide by 17 ft long. What is the surface area of the filters?

8. What is the cross-sectional surface area, in square feet, of an 8-in. pipe?

9. What is the cross-sectional surface area, in square feet, of a 16-in. pipe?

ADDITIONAL NOTES

Volume Measurements

OBJECTIVES

After completing study of this chapter, you should understand:

- how to compute volume measurements of shapes such as boxes, cylinders, cones, and spheres
- common applications of volume measurements in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 10, Volume Measurements.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definitions of the terms *volume*, *cube*, and *area of surface*:

2. Rectangles, triangles, and circles:

3. Volume formulas:

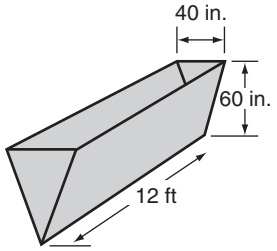
4. Examples:

5. Cones and spheres:

REVIEW QUESTIONS

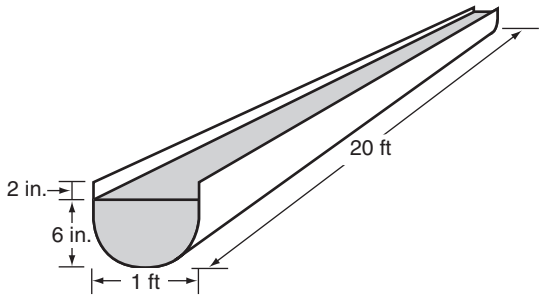
1. A sedimentation basin is 10 m wide and 40 m long, with water to a depth of 4 m. How many cubic meters of water are in the tank?

2. Determine the cubic-foot capacity of the container shown below:

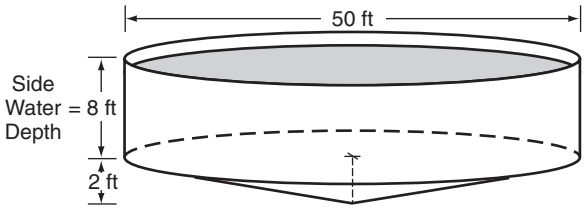


3. A circular clarifier has a diameter of 8 m and is 4 m deep. If the depth of the water is 3 m, how many cubic meters of water are in the tank?

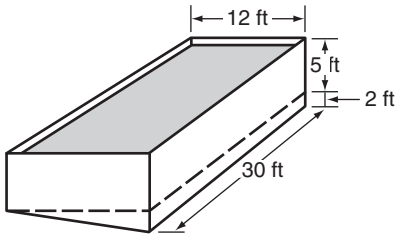
4. One segment of a radial launder system is shown below. Given the average water depth as shown in the diagram, how many cubic feet of water are carried in this radial launder? (Assume that the bottom cross-sectional area of the launder is a half-circle.)



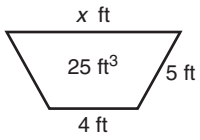
5. The circular clarifier shown below has a conical bottom. With a side water depth of 8 ft, a cone depth of 2 ft, and a diameter of 50 ft, how many cubic feet of water are in the clarifier?



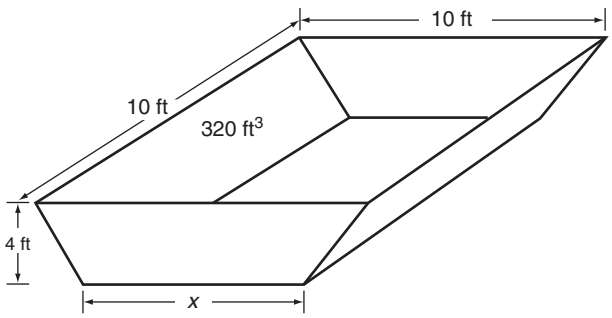
6. A tank with a sloping bottom has dimensions and a water depth as shown below. How many gallons of water are in this tank?



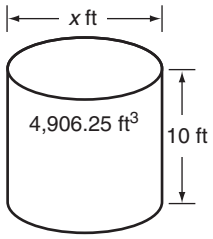
7. What is the length of the unknown side below?



8. What is the length of the unknown base below?



9. What is the diameter of the cylinder?



10. If you had a rectangular detention basin that was 40 ft wide, 40 ft long, and had 16 ft of water in it, how many cubic feet of water would the basin hold?

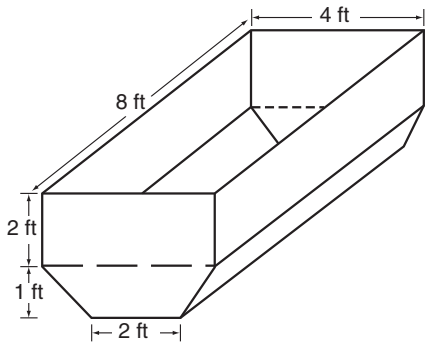
11. How many gallons of water are in the detention basin in question 10 ($1\ ft^3 = 7.48$ gal)?

12. If the detention basin in question 10 was empty and you had a flow rate of 1,200 gpm (gallons per minute), how long, in minutes, would it take to fill the basin to a water level of 16 ft?

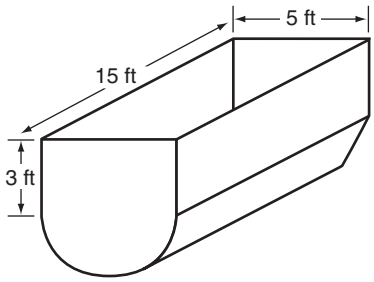
$$\left(\frac{\_\_\_\ \text{gal}}{1}\right)\left(\frac{\text{min}}{1{,}200\ \text{gal}}\right) = \_\_\_\_\_\ \text{min}$$

13. Referring to question 12, how long, in minutes, would it take to fill the basin to the same water level?

14. What is the volume of the combined-shape object pictured below?



15. What is the volume of the combined-shape object pictured below?



ADDITIONAL NOTES

Conversions

OBJECTIVES

After completing study of this chapter, you should understand:

- how to use conversion tables
- methods used for converting units
- common unit conversions required in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 11, Conversions.

OTHER ASSIGNMENTS

CLASS NOTES

1. General discussion:

2. Conversion tables:

3. Box method:

4. Conversions of US customary units:

5. Concentration conversions:

6. Metric system conversions:

7. Temperature conversions:

REVIEW QUESTIONS

1. Converting from cubic feet to gallons to pounds:

   a. Express 1,500 ft^3 in terms of gallons.

   b. Convert 1,000,000 lb of water to cubic feet.

   c. If a tank has a capacity of 25,000 gal of water, what is its capacity expressed in pounds?

2. Flow conversions:

   a. Convert 5 ft^3/s to gallons per day (gpd).

   b. Convert the flow rate of 16,000,000 lb/d to cubic feet per second.

   c. The flow in a water main is 4.5 mgd (million gallons per day). Assuming the flow is steady and continuous, what is this flow rate expressed in cubic feet per second?

   d. The flow to a filter is 1,700 gpm (gallons per minute). Express this flow rate as gallons per day.

   e. The influent meter to a water treatment plant reads 1,700 gpm. If you maintain this flow for 24 hours, what would the total water treated, in million gallons per day, be for the day?

3. Linear measurement conversions:

   a. Convert 4.7 ft to inches.

   b. During backwashing, the water level drops 20 in. How many feet does it drop?

4. Area measurement conversions:

   a. Convert 20 yd^2 to square inches.

   b. The surface area of a clarifier is 800 ft^2. Express this area in terms of square yards.

   c. If 5,000 ft^2 are required for a particular storage area, what is this area expressed in terms of acres?

5. Volume measurement conversions:

   a. Convert 500 ft^3 to cubic inches.

   b. The volume of a chemical storage tank is 20 yd^3. How many cubic feet is this?

   c. The volume of sludge drying beds at a plant is 0.5 acre-ft. What is this volume expressed in cubic feet?

6. Converting from milligrams per liter and grains per gallon (gpg):

   a. Convert 180 mg/L to grains per gallon.

   b. Express the concentration of 12 gpg in terms of milligrams per liter.

   c. The dosage rate for alum at a treatment plant is 30 mg/L. What is this dosage rate expressed in terms of grains per gallon?

7. Metric system conversions:

   a. Convert 14.5 m to millimeters.

   b. Express 150 mL in terms of liters.

   c. Convert 2 km^2 to square meters.

   d. Convert 20,000 cm^3 to cubic meters.

e. The filter loading at a treatment plant is 4 gpm/ft^2. Using the conversion table in appendix A in the *Basic Science Concepts and Applications* text, express this loading rate as millimeters per second.

f. The daily flow rate at a plant is 20 ML/d (megaliters per day). Using the conversion table in appendix A in the text, express this flow rate in million gallons per day.

8. Temperature conversions:

a. Using the three-step conversion procedure, convert 60°F to degrees Celsius.

b. Using the three-step conversion procedure, convert 60°C to degrees Fahrenheit.

c. The raw water entering a treatment plant is 57°F. What is this temperature expressed in degrees Celsius? (Use the temperature conversion table given in appendix A in the text.)

d. The temperature in a storeroom is 30°C. What is the temperature expressed in degrees Fahrenheit? (Use the temperature conversion table given in appendix A in the text.)

ADDITIONAL NOTES

Graphs and Tables

OBJECTIVES

After completing study of this chapter, you should understand:

- how to read and construct graphs and tables
- the purpose of various graphs and tables used in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 12, Graphs and Tables.

OTHER ASSIGNMENTS

CLASS NOTES

1. Purpose of graphs and tables:

2. Types of graphs:

3. Scales:

4. Bar graphs:

5. Circle graphs:

6. Line graphs:

7. Nomographs:

8. Constructing simple graphs:

9. Tables:

REVIEW QUESTIONS

1. Use the typical breakpoint chlorination graph in Figure M12–Q-1 to answer the following questions:

   a. What is the maximum combined chlorine residual shown on the graph (expressed in milligrams per liter)?

   b. As shown on the graph, what happens when 0.5 to 0.8 mg/L of chlorine is added to the water?

   c. How much chlorine must be added before free available chlorine residual begins to form?

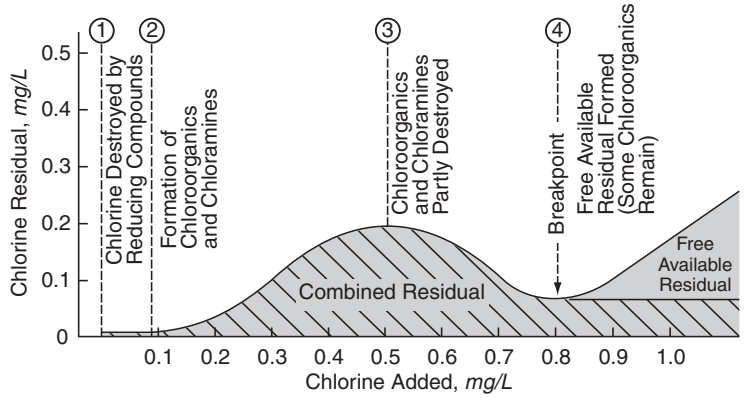


FIGURE M12–Q-1 Breakpoint chlorination

2. The graph shown in Figure M12–12 of the *Basic Science Concepts and Applications* text illustrates typical jar test results when aluminum sulfate is used as a coagulant for a water treatment system. According to this graph, what is the relationship between turbidity and increasing concentrations of alum added to the water?

3. Use the 7-day circular recorder chart shown in Figure M12–13 of the text to determine the flow rate in gallons per minute (gpm) at

   a. 9 p.m. Friday

   b. 9 a.m. Sunday

4. The graph in Figure M12–Q-4 shows the relationship between pH and alkalinity. Based on this graph, answer the following questions:

   a. What part of the graph indicates water that would neither cause carbonate deposits nor create serious corrosion?

   b. If a water supply were found to have an alkalinity of 100 mg/L and a pH of 7.5, would you expect carbonate deposits or corrosion in the distribution system?

   c. If a water supply has an alkalinity of 140 mg/L and a pH of 6.75, would you expect this water to be a source of carbonate deposits or corrosion?

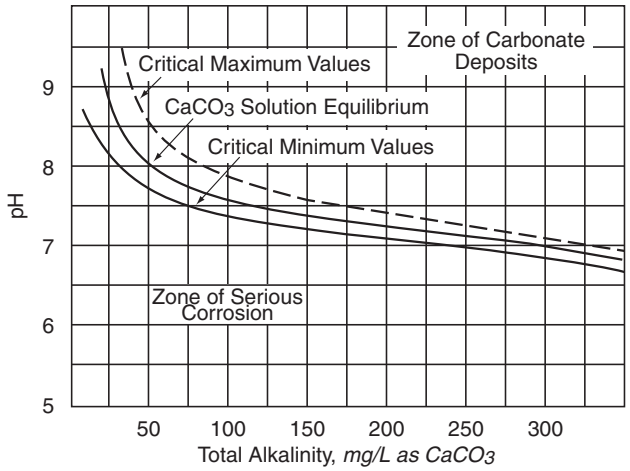


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FIGURE M12–Q-4 Relationship of pH versus alkalinity

5. You are using a pump with the characteristics shown in the graph of Figure M12–18A in the text, and you are pumping against a 95-ft total head. What is the pump capacity, brake horsepower (bhp), and efficiency?

6. A dosage of 12 ppm (parts per million) of dry aluminum sulfate is required for a treatment plant flow of 43 mgd (million gallons per day). Use the nomograph of Figure M12–Q-6 to determine the pounds per day of dry alum needed.

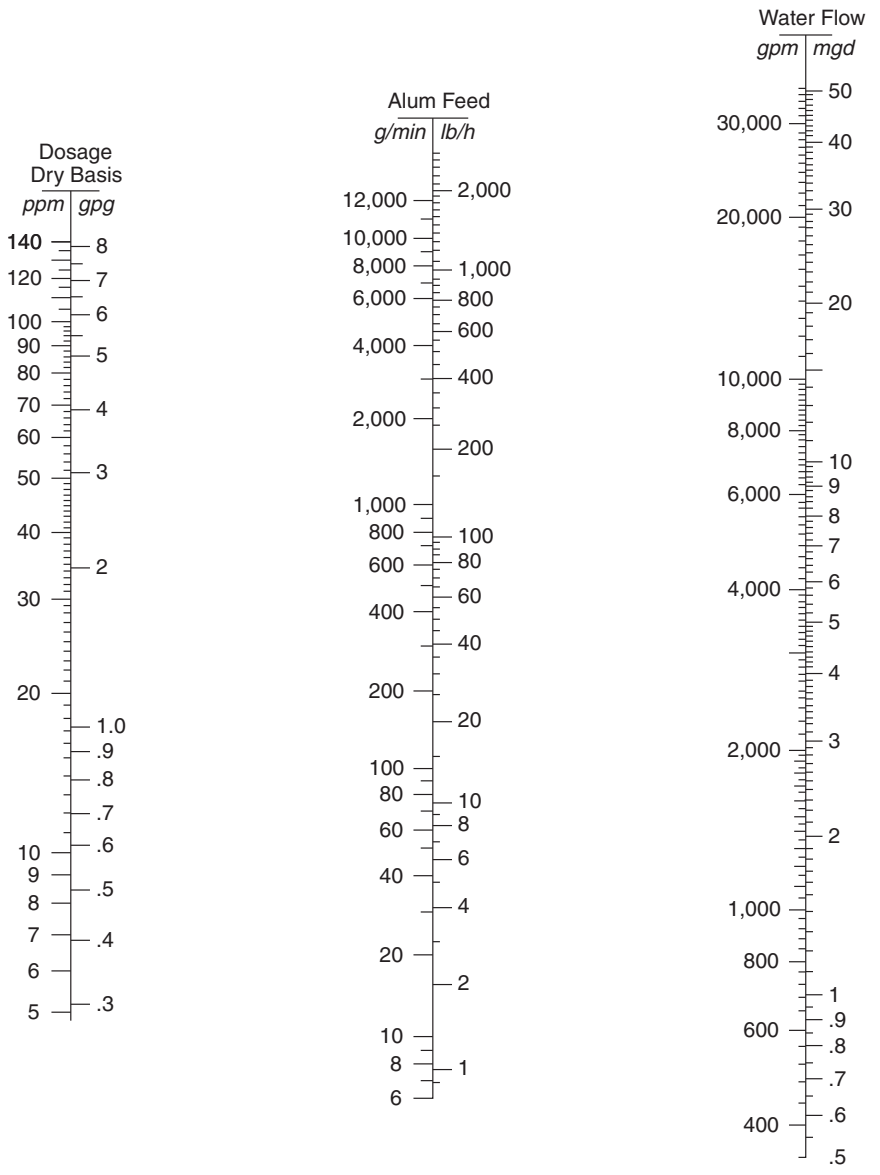

FIGURE M12–Q-6 Dry alum feed nomograph

7. A cylindrical tank has a diameter of 30 ft, and the depth of water in the tank is 5 ft. Use the nomograph of Figure M12–Q-7 to determine how many gallons of water are in the tank.

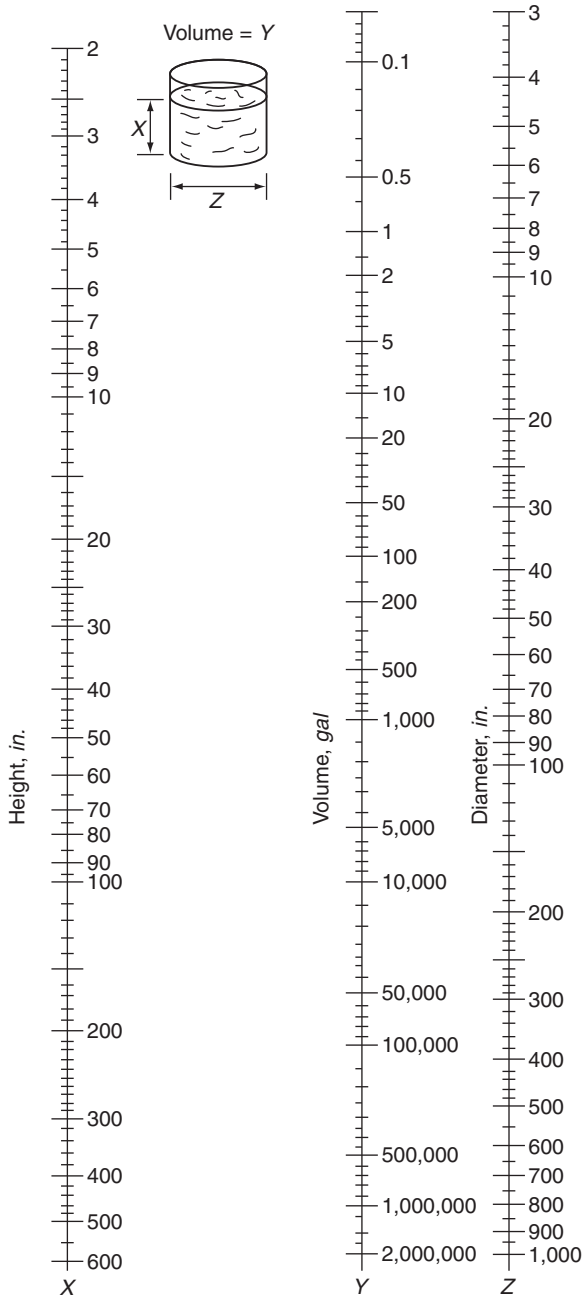

FIGURE M12–Q-7 Capacity of cylindrical tanks

8. A staff gauge measuring the depth of flow over a 60° V-notch weir indicates a head of 0.84 ft. Use Table M12–Q-8 to determine the flow rate in cubic feet per second and million gallons per day.

TABLE M12–Q-8 Discharge of 60° V-notch weirs

Head *ft*	Head, *ft*																			
	.00		.01		.02		.03		.04		.05		.06		.07		.08		.09	
	ft^3/s	*mgd*	ft^3/s	*mgd*	ft^3/s	*mgd*	ft^3/s	*mgd*	ft^3/s	*mgd*	ft^3/s	*mgd*	ft^3/s	*mgd*	ft^3/s	*mgd*	ft^3/s	*mgd*	ft^3/s	*mgd*
0.1	.005	.003	.006	.004	.007	.005	.009	.006	.011	.007	.013	.008	.015	.010	.017	.011	.020	.013	.023	.015
0.2	.026	.017	.029	.019	.033	.021	.037	.024	.041	.026	.045	.029	.050	.032	.055	.035	.060	.039	.065	.042
0.3	.071	.046	.077	.050	.084	.054	.090	.058	.097	.063	.105	.068	.112	.073	.120	.078	.128	.083	.137	.089
0.4	.146	.094	.155	.100	.165	.107	.175	.113	.185	.120	.196	.127	.207	.134	.219	.141	.230	.149	.243	.157
0.5	.255	.165	.268	.173	.281	.182	.295	.191	.309	.200	.324	.209	.339	.219	.354	.229	.370	.239	.386	.249
0.6	.402	.260	.419	.271	.437	.282	.455	.294	.473	.306	.492	.318	.511	.330	.530	.343	.550	.356	.571	.369
0.7	.592	.382	.613	.396	.635	.410	.657	.425	.680	.439	.703	.454	.727	.470	.751	.485	.775	.501	.801	.517
0.8	.826	.534	.852	.551	.879	.568	.906	.585	.933	.603	.961	.621	.990	.640	1.02	.658	1.05	.678	1.08	.697
0.9	1.11	.717	1.14	.737	1.17	.757	1.20	.778	1.24	.799	1.27	.820	1.30	.842	1.34	.864	1.37	.887	1.41	.910
1.0	1.44	.933	1.48	.956	1.52	.980	1.55	1.00	1.59	1.03	1.63	1.05	1.67	1.08	1.71	1.10	1.75	1.13	1.79	1.16
1.1	1.83	1.18	1.87	1.21	1.92	1.24	1.96	1.27	2.00	1.29	2.05	1.32	2.09	1.35	2.14	1.38	2.18	1.41	2.23	1.44
1.2	2.28	1.47	2.32	1.50	2.37	1.53	2.42	1.56	2.47	1.60	2.52	1.63	2.57	1.66	2.62	1.69	2.67	1.73	2.73	1.76
1.3	2.78	1.80	2.83	1.83	2.89	1.87	2.94	1.90	3.00	1.94	3.06	1.97	3.11	2.01	3.17	2.05	3.23	2.09	3.29	2.12
1.4	3.35	2.16	3.41	2.20	3.47	2.24	3.53	2.28	3.59	2.32	3.65	2.36	3.72	2.40	3.78	2.44	3.85	2.48	3.91	2.53
1.5	3.98	2.57	4.04	2.61	4.11	2.66	4.18	2.70	4.25	2.74	4.31	2.79	4.39	2.83	4.46	2.88	4.53	2.93	4.60	2.97
1.6	4.67	3.02	4.75	3.07	4.82	3.12	4.89	3.16	4.97	3.21	5.05	3.26	5.12	3.31	5.20	3.36	5.28	3.41	5.36	3.46
1.7	5.43	3.51	5.52	3.57	5.60	3.62	5.68	3.67	5.76	3.72	5.85	3.78	5.93	3.83	6.01	3.89	6.10	3.94	6.19	4.00
1.8	6.27	4.05	6.36	4.11	6.45	4.17	6.54	4.22	6.63	4.28	6.72	4.34	6.81	4.40	6.90	4.46	6.99	4.52	7.09	4.58
1.9	7.18	4.64	7.28	4.70	7.37	4.76	7.47	4.83	7.56	4.89	7.66	4.95	7.76	5.02	7.86	5.08	7.96	5.14	8.06	5.21
2.0	8.16	5.28	8.27	5.34	8.37	5.41	8.47	5.48	8.58	5.54	8.68	5.61	8.79	5.68	8.90	5.75	9.00	5.82	9.11	5.89

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9. Suppose that contracted rectangular weirs (weirs with end contractions) are used to measure flow at your water treatment plant. The weir crest is 3 ft long and the staff gauge indicates that water is flowing to a depth of 0.25 ft. Use Table M12–Q-9 to determine the flow rate in million gallons per day.

TABLE M12–Q-9 Flow through rectangular weirs with end contractions

	Length of Weir Crest, *ft*											
	1		1½		2		3		4		5	
ft	ft^3/s	*mgd*	ft^3/s	*mgd*	ft^3/s	*mgd*	ft^3/s	*mgd*	ft^3/s	*mgd*	ft^3/s	*mgd*
.01	.003	.002	.005	.003	.007	.004	.010	.006	.013	.009	.016	.011
.02	.009	.006	.014	.009	.019	.012	.028	.018	.038	.024	.047	.030
.03	.017	.011	.026	.017	.034	.022	.052	.034	.069	.045	.086	.056
.04	.026	.017	.040	.026	.053	.034	.080	.052	.106	.069	.133	.086
.05	.037	.024	.055	.036	.074	.048	.111	.072	.148	.096	.186	.120
.06	.048	.031	.073	.047	.097	.063	.146	.094	.195	.126	.244	.158
.07	.061	.039	.091	.059	.123	.079	.184	.119	.246	.159	.308	.199
.08	.074	.048	.112	.072	.149	.097	.225	.145	.300	.194	.375	.243
.09	.088	.057	.133	.086	.178	.115	.268	.173	.358	.231	.448	.289
.10	.103	.067	.155	.101	.208	.135	.313	.203	.418	.271	.523	.339
.11	.119	.077	.178	.116	.241	.155	.363	.234	.485	.312	.607	.390
.12	.135	.087	.204	.132	.273	.177	.411	.266	.549	.355	.687	.445
.13	.152	.098	.230	.149	.308	.199	.464	.300	.620	.401	.776	.501
.14	.169	.110	.256	.166	.343	.222	.517	.335	.691	.447	.865	.560
.15	.188	.121	.285	.184	.382	.246	.576	.372	.770	.496	.964	.621
.16	.206	.133	.313	.202	.419	.271	.632	.408	.845	.546	1.058	.684
.17	.225	.146	.342	.221	.458	.296	.691	.447	.924	.598	1.157	.748
.18	.245	.158	.372	.240	.499	.323	.753	.487	1.007	.651	1.261	.815
.19	.266	.171	.404	.260	.542	.349	.818	.527	1.094	.706	1.370	.884
.20	.286	.185	.435	.281	.584	.377	.882	.569	1.180	.762	1.478	.954
.21	.308	.198	.468	.302	.629	.405	.950	.612	1.271	.819	1.592	1.026
.22	.329	.212	.501	.323	.673	.434	1.017	.656	1.361	.878	1.705	1.100
.23	.350	.226	.534	.345	.717	.463	1.084	.701	1.451	.938	1.818	1.175
.24	.373	.241	.569	.367	.765	.494	1.157	.746	1.549	.999	1.941	1.252
.25	.395	.255	.603	.390	.811	.524	1.227	.793	1.643	1.062	2.059	1.330
.26	.419	.270	.640	.413	.860	.555	1.303	.840	1.745	1.125	2.187	1.410
.27	.442	.285	.675	.436	.909	.587	1.376	.889	1.843	1.190	2.310	1.492
.28	.465	.301	.712	.460	.958	.619	1.451	.938	1.944	1.256	2.437	1.575
.29	.489	.316	.750	.484	1.009	.652	1.529	.988	2.049	1.324	2.569	1.659
.30	.514	.332	.788	.509	1.061	.685	1.608	1.039	2.155	1.392	2.702	1.745
.31	.539	.348	.827	.534	1.114	.719	1.689	1.090	2.264	1.461	2.839	1.832
.32	.564	.364	.866	.559	1.167	.754	1.770	1.143	2.373	1.532	2.976	1.921
.33	.589	.381	.905	.585	1.220	.788	1.851	1.196	2.482	1.603	3.113	2.011
.34	.651	.397	.945	.610	1.275	.824	1.935	1.250	2.595	1.676	3.225	2.102
.35	.642	.414	.987	.637	1.332	.859	2.022	1.304	2.712	1.750	3.402	2.195

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10. Construct a bar graph illustrating the following monthly chlorine-use data.

Month	Chlorine Used (lb)
January	5,200
February	3,400
March	4,500
April	5,500
May	7,200
June	15,400
July	16,500
August	12,600
September	9,200
October	6,100
November	5,900
December	4,400

11. The allocation of tax dollars for a community is shown here. Construct a circle graph depicting this information.

Schools	$ 13,500,000
Streets	1,687,500
Water	2,250,000
Wastewater disposal	1,125,000
Refuse disposal	1,125,000
Administration	2,250,000
Miscellaneous	562,500

12. The amount of polymer (rounded to the nearest 5 lb) used each month during 2002 is given here. Construct a broken-line graph depicting this information.

Month	Polymer Used (lb)
January	90
February	95
March	110
April	160
May	480
June	555
July	530
August	495
September	220
October	115
November	445
December	230

ADDITIONAL NOTES

Per Capita Water Use

OBJECTIVES

After completing study of this chapter, you should understand:

- how to calculate per capita water use
- the importance and uses of per capita water use data in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 13, Per Capita Water Use.

OTHER ASSIGNMENTS

CLASS NOTES

1. Per capita water use data:

2. Formula for gallons per capita per day:

3. Definition of the term *total number of people*:

REVIEW QUESTIONS

1. A water system serves a population of 110,800. If the average daily water use during 1 week was 38.8 mgd (million gallons per day), what was the average gallons-per-capita-per-day (gpcd) water use?

2. A water system serves a population of 57,500. The average daily water use during July was 16.6 mgd. Using the percents listed here, determine the gallons-per-capita-per-day water use for each of the three categories:

Domestic uses	62 percent
Commercial uses	27 percent
Public uses	11 percent

3. The 2002 average per capita water use for a water system was 236 gpcd. If the water system serves a population of 45,700, what was the average daily water use, in gallons per day, for that period?

4. Suppose that the average daily flow for a water system in 2002 was 2.8 ML/d (megaliters per day). If the average per capita water use for that period was 780 L/d per capita, how many people did that water system serve?

ADDITIONAL NOTES

MATHEMATICS 14

Domestic Water Use Based on Household Fixture Rates

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of calculating estimated domestic water use based on household fixtures
- how household fixture unit information is used in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 14, Domestic Water Use Based on Household Fixture Rates.

OTHER ASSIGNMENTS

CLASS NOTES

1. Four principal water use categories:

2. Household fixture use rate:

REVIEW QUESTIONS

1. Using the household fixture use rates in Table M14–1 in the *Basic Science Concepts and Applications* text and the water use listed here for a family of five, calculate the average amount of water used by this household each day. (When a range is given in the table for the approximate rate, use the higher value.)

Laundry	4 loads per week
Showers	4 per day
Tub baths	1 per day
Dishwashing	2 loads per day
Toilet	15 flushes per day
Drinking water	5 people
Garbage disposal	2 min per day
Lawn watering	2,100 ft^2

2. The principal water uses of a family of two are listed here. Use this information and the approximate values given in Table M14–1 in the text to calculate total family water use. (When a range is given in the table for the approximate rate, use a median value.)

Laundry	2 loads per week
Showers	2 per day
Dishwashing	4 loads per week
Toilet	4 flushes per day
Drinking water	2 people
Garbage disposal	3 min per week
Lawn watering	1,000 ft^2

Identify the following:

a. the average amount of water used daily by this family

b. the amount of water used by the family in gallons per capita per day (gpcd)

c. the one activity that represents the highest water use per day

ADDITIONAL NOTES

MATHEMATICS 15

Water Use per Unit of Industrial Product Produced

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of calculating water use per unit of industrial product produced
- how data on water use per unit of industrial product produced are used in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 15, Water Use per Unit of Industrial Product Produced

OTHER ASSIGNMENTS

CLASS NOTES

1. Definition:

2. Table M15–1: Water requirements in selected industries:

REVIEW QUESTIONS

1. A new ammonia plant is scheduled to be built in your area. The peak production of this plant is expected to be 18 tons per day. If this industry expects to obtain its water requirements from your treatment plant, how much water will be required from your treatment plant daily? (Use Table M15–1 in the *Basic Science Concepts and Applications* text for water requirements per product.)

2. An industry that manufactures steel requires 68,000 L of water per 1,000 kg of steel produced. Suppose that the 2002 steel production for this industry was 18,720,000 kg. Assuming 312 days of production during 2002, on the average, how much water was required each day of production?

ADDITIONAL NOTES

MATHEMATICS 16

Average Daily Flow

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of calculating average daily flow for a water system
- how average daily flow data are used in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 16, Average Daily Flow.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definition and formula:

2. Importance in operations:

REVIEW QUESTIONS

1. The total amounts of water treated for the months of June, July, and August are listed here. Using this information, calculate the average daily flow (ADF) for this 3-month period.

June	95,440,000 gal
July	107,913,000 gal
August	115,359,000 gal

2. A water treatment plant reported that the total water treated for the calendar year 1992 (a leap year) was 9,975 mil gal. What was the annual average daily flow (AADF) for that year?

3. The following total monthly flows (in million liters) were recorded for the year. Based on this information, what was the AADF for the year?

January	172.91	July	192.55
February	174.03	August	189.41
March	179.62	September	186.07
April	181.13	October	181.92
May	181.79	November	178.66
June	186.68	December	174.32

4. The ADF (in million gallons per day) for each month of 1995 are listed below. Using this information, determine the AADF.

January	1.71	July	2.44
February	1.88	August	2.27
March	1.83	September	2.06
April	1.91	October	1.93
May	1.97	November	1.85
June	2.13	December	1.76

ADDITIONAL NOTES

MATHEMATICS 17

Surface Overflow Rate

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of calculating surface overflow rate
- how surface overflow rate data are used in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 17, Surface Overflow Rate.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definition and formula:

2. Importance in operations:

REVIEW QUESTIONS

1. The flow to a sedimentation tank is 2.02 mgd (million gallons per day). If the tank is 80 ft long and 20 ft wide, what is the surface overflow rate in gallons per day per square foot (gpd/ft^2)?

2. A circular clarifier has a diameter of 60 ft. If the flow to the clarifier is 2.8 mgd, what is the surface overflow rate in gallons per day per square foot?

3. A sedimentation tank receives a flow of 11.250 ML/d (megaliters per day). If the surface overflow rate is 45,000 L/d/m^2 and the length of the tank is 30 m, what is the width of the tank in meters?

4. With a flow rate of 2.52 mgd, what is the surface overflow rate, in gallons per day per square foot, for a rectangular clarifier 40 ft wide, 120 ft long, with a 14-ft side water depth (SWD) and a total weir length of 670 ft?

5. There are two sedimentation basins 40 ft in diameter with 14-ft SWDs and flow rates of 0.71 mgd. What is the surface overflow rate in gallons per day per square foot?

6. There are two sedimentation basins 48 ft in diameter with 17-ft SWDs and flows of 2.33 mgd. What is the surface overflow rate in gallons per day per square foot?

7. There are three sedimentation basins 45 ft in diameter with 16-ft SWDs and flow rates of 1.86 mgd. With one basin out of service for maintenance, what is the surface overflow rate in gallons per day per square foot?

ADDITIONAL NOTES

Weir Overflow Rate

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of calculating weir overflow rate
- how weir overflow rate data are used in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 18, Weir Overflow Rate.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definition and formula:

2. Importance in operations:

REVIEW QUESTIONS

1. A sedimentation tank has a total of 120 ft of weir over which the water flows. What is the weir overflow rate, in gallons per day per foot (gpd/ft), when the flow is 1.4 mgd (million gallons per day)?

2. The diameter of the weir in a circular clarifier is 55 ft. What is the weir overflow rate if the flow over the weir is 2.24 mgd?

3. The weir overflow rate for a sedimentation tank is 124,800 L/d/m, and the tank has a total of 35 m of weir over which the water flows. What is the megaliters-per-day (ML/d) flow over the weir?

4. A circular clarifier receives a flow of 1,931,000 gpd. The weir overflow for the clarifier is 12,300 gpd/ft. What is the diameter of the weir?

5. If you have two sedimentation basins that are 40 ft in diameter with 14-ft side water depths (SWDs) and flow rates of 0.710 mgd, what is the weir overflow rate, in gallons per day per foot, under these conditions?

6. What is the weir overflow rate, in gallons per day per foot, of two circular sedimentation basins that are 48 ft in diameter with 17-ft SWDs and flow rates of 2.33 mgd?

7. What is the weir overflow rate, in gallons per day per foot, of three sedimentation basins that are 45 ft in diameter with 16-ft SWDs, and flow rates of 1.86 mgd?

ADDITIONAL NOTES

MATHEMATICS 19

Filter Loading Rate

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of calculating filter loading rate
- how filter loading rate data are used in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 19, Filter Loading Rate.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definition and formulas:

2. Typical loading rates:

REVIEW QUESTIONS

1. A rapid sand filter is 12 ft wide and 20 ft long. If the flow through the filter is 0.83 mgd (million gallons per day), what is the filter loading rate in gallons per minute per square foot (gpm/ft^2)?

2. How many inches drop per minute corresponds to a filter loading rate of 1.9 gpm/ft^2?

3. What is the filter loading rate, in liters per minute per square meter, of a sand filter in which the water level dropped 250 mm within 3 min after the influent valve was closed?

4. What is the filter capacity, in millions of gallons per day, of a treatment plant that has four rapid sand filters, each 14 ft wide and 15 ft long, with filter loading rates of 3 gpm/ft^2?

ADDITIONAL NOTES

Filter Backwash Rate

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of calculating filter backwash rate
- how filter backwash rate data are used in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 20, Filter Backwash Rate.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definition:

2. Formulas:

3. Examples:

REVIEW QUESTIONS

1. A rapid sand filter is 15 ft wide and 30 ft long. If the backwash water flow rate is 12 mgd (million gallons per day), determine the filter backwash rate in gallons per minute per square foot (gpm/ft^2).

2. What is the filter backwash rate, in inches per minute, corresponding to a filter backwash rate of 16 gpm/ft^2?

3. During backwashing of a rapid sand filter, the operator measured the backwash flow rate to be 27 in./min. Express this filter backwash rate in gallons per minute per square foot.

ADDITIONAL NOTES

Mudball Calculation

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of calculating percent volume of mudballs in a filter
- how mudball calculation information is used in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 21, Mudball Calculation.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definition:

2. Formula:

3. Examples:

REVIEW QUESTIONS

1. A sample taken from the filter for mudball determination has a volume of 4,900 mL. If the volume of mudballs in the sample is found to be 165 mL, what is the percent volume of mudballs in the sample?

2. A mudball test on a filter shows that there is an 88-mL volume of mudballs in the 3,500-mL sample. What is the percent volume of mudballs in the sample?

ADDITIONAL NOTES

Detention Time

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of determining detention time in a basin
- how detention time is used in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 22, Detention Time.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definition:

2. Typical detention times:

3. Formula:

4. Actual detention time compared to theoretical time:

REVIEW QUESTIONS

1. A flash mixing basin has a capacity of 2,400 gal. If the flow rate to the basin is 43 gps (gallons per second), what is the detention time in seconds?

2. A sedimentation tank is 20 m long and 4 m wide and has water to a depth of 4 m. If the flow rate to the tank is 86,400 L/h, what is the detention time in hours?

3. A flocculation basin has a capacity of 30,000 gal. If the flow rate to the basin is 1,728,000 gpd (gallons per day), what is the detention time in minutes?

4. A circular clarifier receives a flow of 4.2 mgd (million gallons per day). If the detention time in the clarifier is 1.8 hours, what is the capacity of the clarifier in gallons?

5. With a flow rate of 2.52 mgd, what is the detention time, in hours and minutes, in a rectangular clarifier that is 40 ft wide, 120 ft long, with a 14-ft side water depth (SWD) and a total weir length of 670 ft?

6. What is the detention time, in hours and minutes, in a 12-in.-diameter pipe, 6,000 ft long, with a flow rate of 0.2 mgd?

7. What is the detention time, in hours and minutes, of two sedimentation basins that are 40 ft in diameter with 14-ft SWDs and flow rates of 0.71 mgd?

8. What is the detention time, in hours and minutes, of two circular sedimentation basins that are 48 ft in diameter with 17-ft SWDs and flow rates of 2.33 mgd?

9. What is the detention time, in hours and minutes, of three sedimentation basins 45 ft in diameter with 16-ft SWDs and flow rates of 1.86 mgd? One of the three basins is out of service for maintenance.

ADDITIONAL NOTES

MATHEMATICS 23

Well Problems

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of calculating well yield, drawdown, and specific capacity
- how these computations are used in water well operation and maintenance

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Mathematics 23, Well Problems.

OTHER ASSIGNMENTS

CLASS NOTES

1. Well yield:

2. Drawdown:

3. Specific capacity:

REVIEW QUESTIONS

1. For a certain test of well yield, it took 29 s to fill a 55-gal barrel. Based on this pumping rate, what is the well yield in gallons per minute (gpm)?

2. What is the well yield, in gallons per minute per foot (gpm/ft), if it takes a pump 1 min 46 s to fill a tank that is 3 ft wide and 4 ft long to a depth of 3 ft?

3. The water level in a well is 19 m from ground surface when the pump is not in operation. If the water level is 31 m below ground surface when the pump is in operation, what is the drawdown in meters?

4. If the well yield was 210 gpm when the drawdown for the well was 72 ft, what was the specific capacity of the well, in gallons per minute per foot, at that time?

5. It takes a pump 0.34 min to fill a 55-gal barrel. If the water level in the well is 70 ft below ground surface when the pump is not in operation and 83 ft below ground surface when the pump is in operation, what is the specific capacity of the well in gallons per minute per foot?

ADDITIONAL NOTES

Hydraulics

Density and Specific Gravity

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of calculating density and specific gravity
- how density and specific gravity are used in calculations in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Hydraulics 1, Density and Specific Gravity.

OTHER ASSIGNMENTS

CLASS NOTES

1. Density:

2. Specific gravity:

3. Specific gravity of gases:

REVIEW QUESTIONS

1. The weight of 3 ft^3 of mercury is 2,546 lb.

   a. What is the density of mercury?

   b. What is the specific gravity of mercury?

2. The specific gravity of ammonia gas is 0.60. If released, will this gas first accumulate in the ceiling area or in the floor area of a room?

3. If the specific gravity of a load of copper sulfate crystals is 1.41, what is the density, in pounds per cubic foot and kilograms per cubic meter, of the copper sulfate crystals?

4. You are pumping 30 gpm (gallons per minute) of a liquid that has a specific gravity of 1.14. At this rate, how many pounds per day are you pumping?

5. What is the specific gravity of chlorine gas? What happens to chlorine gas if it is released in a room filled with air? Why is this important for water plant operations to understand?

ADDITIONAL NOTES

Pressure and Force

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of calculating pressure and force
- how pressure and force are used in calculations in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Hydraulics 2, Pressure and Force.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definition of the term *pressure*:

2. Pressure:

3. Force:

REVIEW QUESTIONS

1. Convert a pressure of 148 ft of water to pounds per square inch gauge (psig).

2. A pressure of 240 psig is equivalent to how many feet of water?

3. If the water in a tank is 32 ft deep, what is the gauge reading (pounds per square inch gauge) at the bottom of the tank? (See Figure H2–Q-3.)

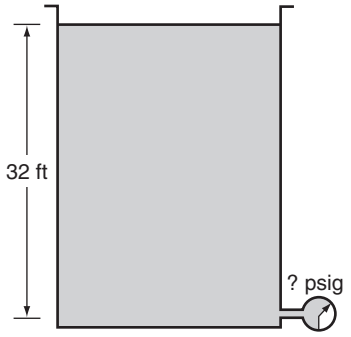


FIGURE H2–Q-3

4. Convert the answer to question 3 to pascals, the unit of pressure in the metric system (refer to Table A–1 in appendix A of the *Basic Science Concepts and Applications* text).

5. A pressure gauge at the ground level of a water tower reads 105 psig.

   a. What is the height from the ground to the water surface in the tower?

   b. Convert the answer in feet of hydraulic head to kilopascals (kPa). (See Figure H2–Q-5.)

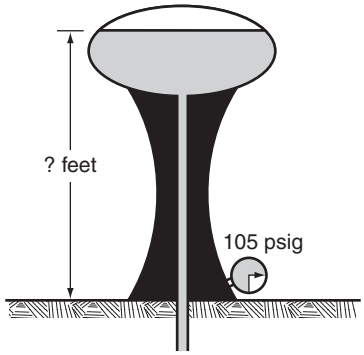


FIGURE H2–Q-5

6. The pressure on a surface is 37 psig. If the surface area is 260 $in.^2$, what is the force, in pounds, exerted on the surface?

7. If there is a pressure of 160 psig pressing against a surface 10 ft by 12 ft, what is the force exerted against the surface?

ADDITIONAL NOTES

Piezometric Surface and Hydraulic Grade Line

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of calculating piezometric surface and hydraulic grade line
- how piezometric surface and hydraulic grade line are used in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Hydraulics 3, Piezometric Surface and Hydraulic Grade Line.

OTHER ASSIGNMENTS

CLASS NOTES

1. Piezometric surface:

2. Hydraulic grade line:

REVIEW QUESTIONS

1. The piezometric surface is 87 ft above a point in a pipeline. What is the pressure, in pounds per square inch gauge (psig), at that point in the pipeline?

2. The distance from the ground surface to water in a nonflowing artesian well is 59 m. The driller's log indicates that the aquifer was first penetrated at a depth of 148 m. How high has the water risen above the top of the artesian aquifer?

3. A cylindrical water storage tank 120 ft in diameter is equipped with a sight glass to monitor water depth in the tank. When full, the water in the tank is 48 ft deep. When the sight glass shows a piezometric surface of 33 ft, how many gallons of water are in the tank?

4. Explain the different levels of the piezometric surfaces in Figure H3–Q-4.

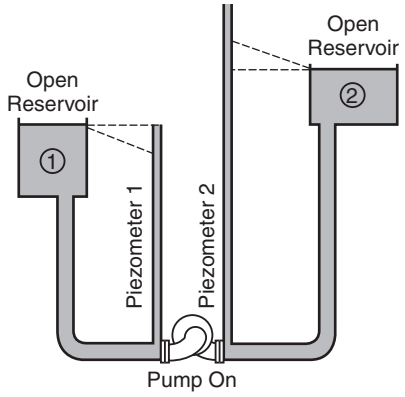


FIGURE H3–Q-4

5. Define the term *hydraulic grade line* (HGL).

6. Draw the HGL for the static water condition shown in Figure H3–Q-6.

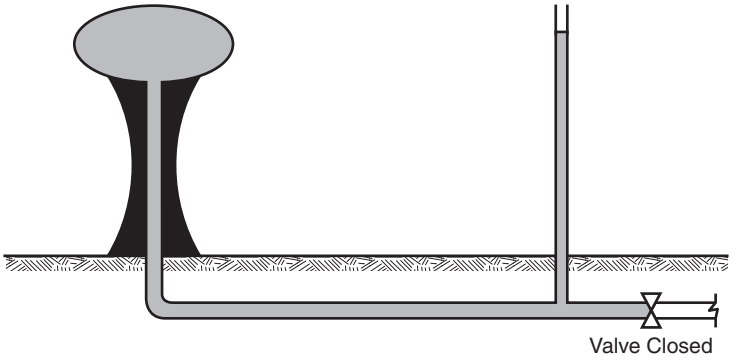


FIGURE H3–Q-6

7. What two basic concepts does Figure H3–Q-6 illustrate regarding HGLs in static water systems?

8. Draw the HGL for the transmission line shown in Figure H3–Q-8.

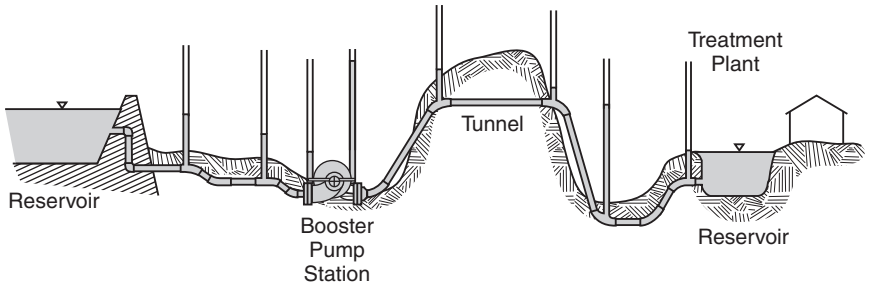


FIGURE H3–Q-8

9. What does it mean when the HGL …

   a. slopes downward?

   b. slopes upward?

   c. is horizontal?

10. If a pressure gauge in a pipeline reads 175 psig, how high above the pipeline is the HGL?

11. The pressure gauge at ground level of a water tower reads 47 psig. The water in the tank is static (the tank is neither filling nor emptying). How high above the ground is the water surface in the tower?

ADDITIONAL NOTES

Head

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of calculating hydraulic head
- how hydraulic head is used in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Hydraulics 4, Head.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definitions of terms:

2. Formula for calculating head:

3. Types of head:

4. Calculating heads:

REVIEW QUESTIONS

1. Express the following gauge pressures as pressure head in feet. Also convert the answers into kilopascals (kPa).

   a. 150 psig (pounds per square inch gauge)

   b. 250 psig

   c. 86 psig

2. What is the depth of water in the open tank in Figure H4–Q-2 if a pressure gauge at the bottom reads 9 psig?

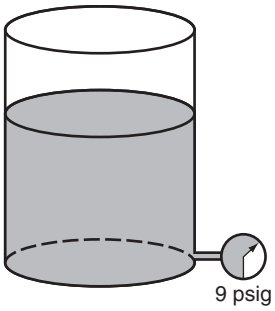


FIGURE H4–Q-2

3. Calculate the pressure heads in feet at points A and B of Figure H4–Q-3, first when the valves are open, and then when the valves are closed, using these gauge pressure readings:

	Valve Open	Valve Closed
Pressure at A	126 psig	174 psig
Pressure at B	108 psig	174 psig

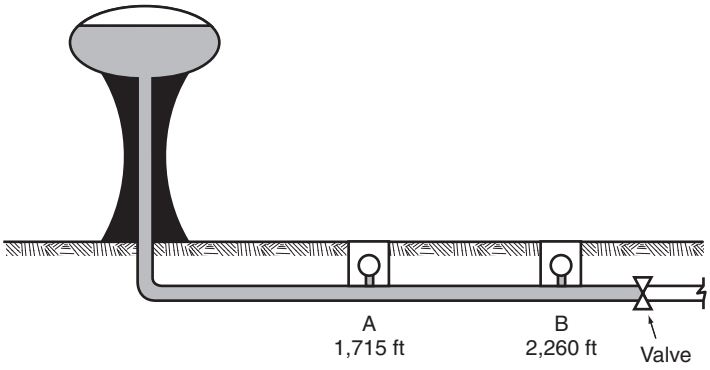


FIGURE H4–Q-3

4. Calculate the pressure head in pounds per square inch gauge on valve 3, Figure H4–Q-4, when valve 3 is closed and the other valves are opened.

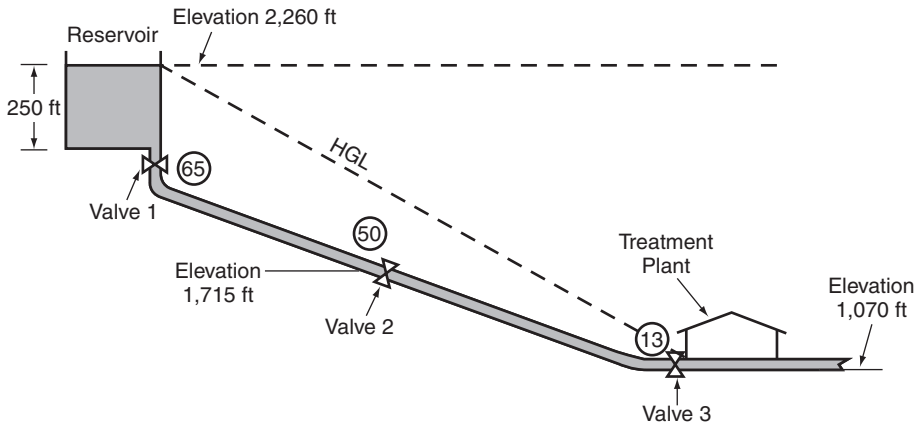


FIGURE H4–Q-4

5. In Figure H4–Q-4, what is the pressure head, in pounds per square inch, on valve 3 if valve 2 is closed before valve 3?

ADDITIONAL NOTES

HYDRAULICS 5

Head Loss

OBJECTIVES

After completing study of this chapter, you should understand:

- methods used to calculate head loss
- how head loss data are used in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Hydraulics 5, Head Loss.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definition of *head loss*:

2. Friction head loss:

3. Minor head loss:

REVIEW QUESTIONS

1. A 12-in.-diameter water transmission line carries water 7,420 ft from a reservoir to a treatment plant. The pipeline is new, reinforced concrete, and the flow rate is 1.8 mgd (million gallons per day). Use Tables H5–1 and H5–2 in the *Basic Science Concepts and Applications* text to determine the friction head loss in this line.

2. What would the friction head loss in the water transmission line in question 1 be if the flow rate is increased to 4.5 mgd (2.5 times 1.8 mgd)?

3. A high-elevation water tank continuously feeds a lower tank at a flow rate of 3,500 gpm (gallons per minute). The tanks are connected by 683 ft of 14-in. cast-iron pipe, about 10 years old. The line contains the following fittings:

   - an entrance (ordinary)
   - a 45° elbow
   - two gate valves, fully open
   - two square elbows

   Use Figure H5–2 and Table H5–3 in the text to determine the total head loss.

ADDITIONAL NOTES

Pumping Problems

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of performing pumping calculations, including determining pumping rates, pump heads, horsepower, and efficiency
- how to read pump curves
- the uses of pump calculations in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Hydraulics 6, Pumping Problems.

OTHER ASSIGNMENTS

CLASS NOTES

1. Pumping rates:

2. Pump heads:

3. Horsepower and efficiency:

4. Reading pump curves:

REVIEW QUESTIONS

1. The totalizer of the meter on the discharge side of your pump reads in hundreds of gallons. At 3:10 p.m., it reads 272; at 4:40 p.m., the totalizer reads 635. Use this information to determine the pumping rate in gallons per minute (gpm).

2. During a 30-min pumping test, 14,720 L of water are pumped into a tank that has a diameter of 3.3 m. The water level before the pumping test was 1 m. What is the pumping rate expressed in liters per minute?

3. A 50-ft-diameter tank has water to a depth of 6 ft. The inlet valve is closed, and a 2-hour pumping test is begun. If the water level in the tank at the end of the test is 2.3 ft, what is the pumping rate in gallons per minute?

4. A pump to be tested will discharge to a tank that is 16 m long and 8 m wide, initially filled with water to a depth of 1.5 m. The outlet valve to the tank is closed, and a pump test is conducted. If the water level in the tank rises 450 mm during the 1-hour test, what is the pumping rate in liters per minute?

5. List the four types of static pump heads and locate three of them on Figure H6–Q-5.

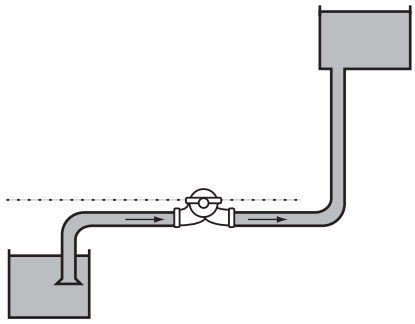


FIGURE H6–Q-5

6. What four terms are used to describe dynamic pumping heads, and where would three of these heads appear in Figure H6–Q-6?

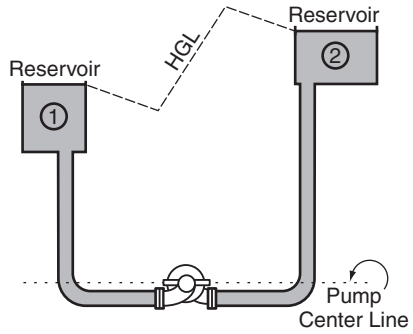


FIGURE H6–Q-6

7. A pump is moving water from reservoir 1 to reservoir 2 as shown in Figure H6–Q-7. Locate, label, and calculate in feet:

   a. the static suction head

   b. the static discharge head

   c. the total static head

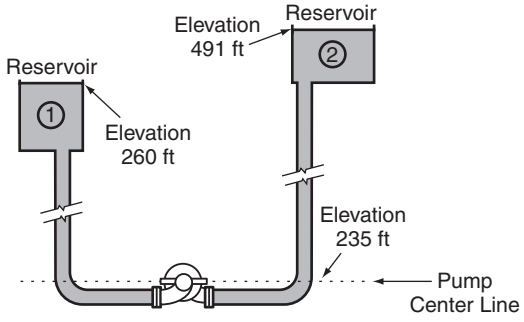


FIGURE H6–Q-7

8. Using the pressure gauge information in Figure H6–Q-8, determine the dynamic heads. Gauge readings are in pounds per square inch (gauge) and were taken when the pump was operating.

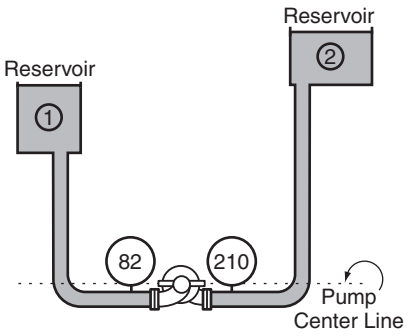


FIGURE H6–Q-8

9. Using the gauge pressure readings shown in Figure H6–Q-9, calculate the dynamic heads. Gauge readings are in pounds per square inch (gauge) and were taken while the pump was operating.

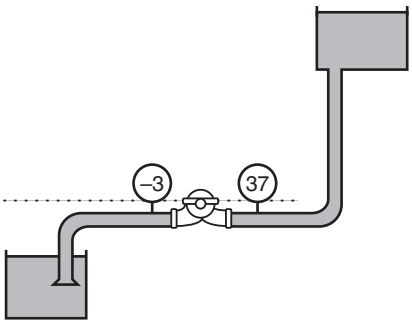


FIGURE H6–Q-9

10. Use the information given in Figure H6–Q-10 to calculate

    a. static suction head

    b. static discharge head

    c. total static head

    d. dynamic suction head

    e. dynamic discharge head

    f. total dynamic head

    g. combined friction and minor head losses, suction side

    h. combined friction and minor head losses, discharge side

    (The pressure gauge readings were taken when the pump was on.)

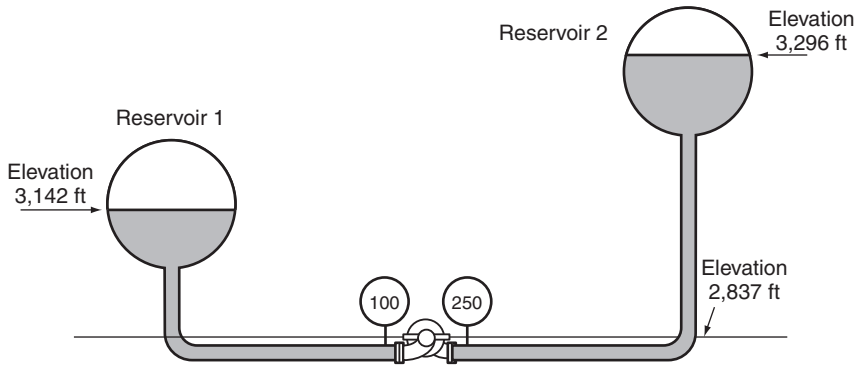


FIGURE H6–Q-10

11. Using the information in Figure H6–Q-11,

    a. calculate the static and dynamic heads

    b. calculate the combined friction and minor head losses, in feet

    c. locate and label each head (gauge pressure readings were taken with the pump on)

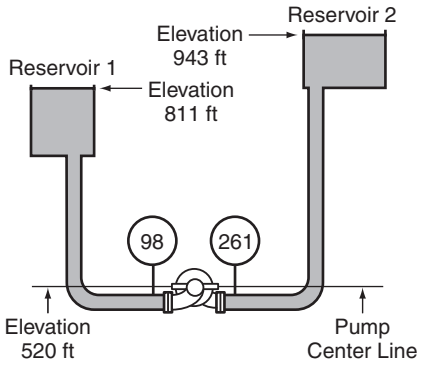


FIGURE H6–Q-11

12. A flow of 1,840 gpm is to be pumped against a total head of 40 ft. What is the water horsepower (whp) required?

13. Suppose you wish to pump a flow of 380 gpm against a total head of 35 ft. If the specific gravity of the liquid to be pumped is 1.2, what is the water horsepower required?

14. A pump is putting out 10 whp and delivering a flow of 810 gpm. What is the total head, in feet, the pump is working against? Assume the pump and motor are 100 percent efficient.

15. What is the maximum pumping rate, in gallons per minute, of a pump producing 8 whp, working against a total head of 43 ft?

16. If a pump that has an efficiency of 80 percent is discharging 590 gpm against a total head of 77 ft, what is the brake horsepower (bhp)?

17. A power of 19 hp (whp) is required for a particular pumping application. If the pump is 80 percent efficient and the motor is 90 percent efficient, what is the motor horsepower (mhp) required?

18. Given a motor output of 24.8 hp and a water horsepower of 20 hp, what is the pump efficiency?

19. You have determined that the minimum motor horsepower requirement of a particular pumping situation is 12 hp. If the cost of power is \$0.031/kW·h, what is the hourly cost of power used by the motor?

20. Given a brake horsepower of 18.5, a motor efficiency of 88 percent, and a cost of power of \$0.015/kW·h, determine the daily power cost for operating a pump.

21. A particular pump is discharging 900 gpm against a total head of 82 ft. The wire-to-water efficiency is 83 percent, and the power rate is \$0.02/kW·h. What is the power cost for 14 hours?

22. Using the pump curve in Figure H6–Q-22, if the pump is producing 1,800 gpm, find the corresponding

    a. total head

    b. power

    c. efficiency

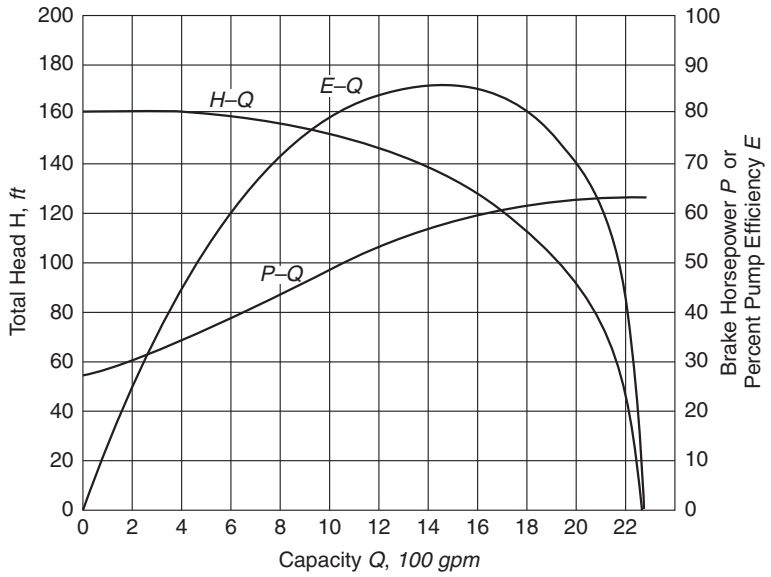


FIGURE H6–Q-22

23. For a total head of 140 ft and using the pump curve (in Figure H6–Q-22), find the pump's

    a. capacity

    b. power

    c. efficiency

24. Power costs are \$0.03/kW·h, total head is 132 ft, and motor efficiency is 85 percent. How much does it cost to operate the pump represented in the pump curve (Figure H6–Q-22) for 20 hours?

25. What is the water horsepower of a high-service pump that has a pumping rate of 550 gpm at 75 psi and an 89 percent motor efficiency and 80 percent pump efficiency?

26. In problem 25, what is the brake horsepower?

27. In problem 25, what is the motor horsepower?

28. What is the wire-to-water (w to w) efficiency?

29. What is the water horsepower on each of the following pumps?

    - Three well pumps that pump 30,000 gph (gallons per hour) at 86.6 psi
    - 87 percent pump efficiencies and 90 percent motor efficiencies
    - The electric cost is \$0.05/kW·h, and the pumps run 9 h 45 min per day

30. What is the brake horsepower on each pump in problem 29?

31. What is the motor horsepower on each pump in problem 29?

32. What is the wire-to-water percentage for problem 29?

33. In problem 29, what is the electric cost per day (\$/d)?

ADDITIONAL NOTES

Flow Rate Problems

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of performing flow rate calculations for pipes and channels
- how commonly used flow-measuring devices operate and are read
- how flow rate calculations are used in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Hydraulics 7, Flow Rate Problems.

OTHER ASSIGNMENTS

CLASS NOTES

1. Reasons for calculating flow rates:

2. Instantaneous flow rate calculations:

3. Flow-measuring devices:

REVIEW QUESTIONS

1. Water in a channel is flowing at the rate of 9.2 ft/s. If the channel is 2.5 ft wide and has water to a depth of 14 in., what is the flow rate, in cubic feet per second, in the channel?

2. What is the flow rate, in gallons per minute (gpm), of water passing through a 6-in. pipe at 7 fps (feet per second)?

3. The flow rate through a 10-in.-diameter pipe is 2.8 mgd (million gallons per day). The pipe is flowing full. What is the velocity in the line in feet per minute?

4. The flow rate in a 3-ft-wide, 16-in.-deep channel measures 5,400 gpm. What is the average water velocity in the channel in feet per second?

5. A float is placed in a channel to estimate the flow velocity and the rate of flow. The float moved a distance of 160 ft in 3 min. The channel is 42 in. wide and 36 in. deep with a side water depth (SWD) of 18 in.

   a. What is the flow rate in the channel in feet per second?

   b. What is the flow rate in the channel in cubic feet per second ?

   c. What is the flow rate in gallons per minute?

   d. What is the flow rate in million gallons per day?

6. Assuming the flow rate remains constant at 3 ft^3/s, how is the velocity of flow affected in a change from a 6-in.-diameter pipe to a 4-in.-diameter pipe?

7. For Figure H7–Q-7, determine the velocity, in feet per second, at point A and the flow rate, in gallons per minute, at points B and C.

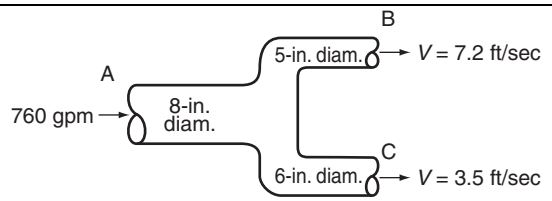


FIGURE H7–Q-7

8. There is a 12-in. pipe carrying a flow of 710 gpm and it flows into a 6-in. pipe.

   a. What is the velocity in the 6-in. pipe in feet per second?

   b. How many 6-in. pipes would it take to maintain the same flow velocity in the 6-in. pipes as in the 12-in. pipe?

9. With a flow rate of 2.52 mgd, what is the flow velocity, in feet per minute (fpm), through a rectangular clarifier that is 40 ft wide, 120 ft long, with a 14-ft SWD and a total weir length of 670 ft?

10. What is the velocity, in feet per second, of a flume that is 2.5 ft wide, 4 ft deep, has a 2.5-ft water depth, with a flow rate of 2,950 gpm?

11. What is the velocity, in feet per second, of a pipeline that is 12 in. in diameter and 6,000 ft long, with a flow rate of 0.2 mgd?

ADDITIONAL NOTES

Thrust Control

OBJECTIVES

After completing study of this chapter, you should understand:

- methods of performing thrust control calculations
- how calculations of thrust are used in water system design and operation

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Hydraulics 8, Thrust Control.

OTHER ASSIGNMENTS

CLASS NOTES

1. Reasons for thrust control:

2. Causes of thrust in water mains:

3. Direction of thrust and effects:

4. Thrust anchor design:

5. Thrust block calculations:

6. Thrust anchor calculations:

REVIEW QUESTIONS

1. What is thrust, and why is it a concern in pipelines?

2. What is the purpose of thrust control?

3. The size and shape of a thrust block are based primarily on five factors. List them.

4. You are installing a horizontal replacement section of 6-in. polyvinyl chloride pipe with push-on joints. The section includes one tee and several 90° and 11¼° bends. On completion, the line will be tested at 300 psig. The soil type throughout the replacement area is sand and gravel. Find the dimensions of the thrust control device required at each type fitting.

ADDITIONAL NOTES

Chemistry

CHEMISTRY 1

The Structure of Matter

OBJECTIVES

After completing study of this chapter, you should understand:

- the basic structure of elements
- how elements are represented in the periodic table
- why knowledge of the structure of elements is important in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Chemistry 1, The Structure of Matter.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definition of the term *element*:

2. Subatomic particles:

3. Atomic structure:

4. The periodic table:

REVIEW QUESTIONS

1. Briefly define the terms *nucleus*, *proton*, *neutron*, and *electron* as they refer to the structure of an atom.

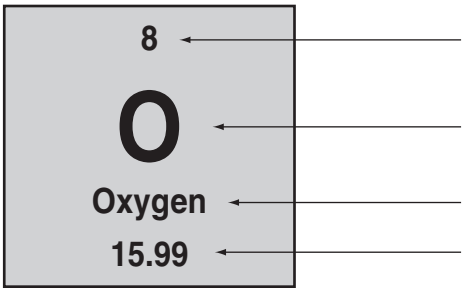
2. What is the charge of each of the following atomic particles: proton, neutron, and electron?

3. What is an isotope?

4. What is an ion?

5. What is the difference between a cation and an anion?

6. In addition to the name of the element, the periodic table has at least four basic types of information, as shown below. Label each arrow.



ADDITIONAL NOTES

The Classification of Matter

OBJECTIVES

After completing study of this chapter, you should understand:

- how matter is classified into pure elements, compounds, and mixtures
- the definition and examples of each classification
- why this knowledge is important in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Chemistry 2, The Classification of Matter.

OTHER ASSIGNMENTS

CLASS NOTES

1. Definition of the term *matter*:

2. Solids, liquids, and gases:

3. Pure elements:

4. Compounds:

5. Mixtures:

REVIEW QUESTIONS

1. Give two examples of elements that exist in pure form.

2. Define the terms *compound* and *mixture*.

3. What is a molecule? Give one example.

4. Give two examples of compounds and two examples of mixtures.

ADDITIONAL NOTES

Valence, Chemical Formulas, and Chemical Equations

OBJECTIVES

After completing study of this chapter, you should understand:

- the principles of valence, chemical formulas, and chemical equations
- the definitions of chemical terms
- why this knowledge is important in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Chemistry 3, Valence, Chemical Formulas, and Chemical Equations.

OTHER ASSIGNMENTS

CLASS NOTES

1. Only certain combinations of elements bond:

2. Valence:

3. Chemical formulas and equations:

4. Determining percent by weight of elements in a compound:

5. Chemical equations:

6. Definition of the term *mole*:

REVIEW QUESTIONS

1. What is a radical?

2. For the following chemical formulas, list the elements present and indicate how many atoms of each element are present in one molecule of each compound:

   a. HOCl

   b. NH_3

   c. $CaCO_3$

   d. $Ca(OCl)_2$

   e. $Al_2(OH)_6$

   f. $Al_2(SO_4)_3$

3. The formula for calcium hydroxide is $Ca(OH)_2$. Calcium represents what percent of the weight of the compound? What percent is represented by oxygen and hydrogen? (Use the periodic table in appendix B of the *Basic Science Concepts and Applications* text to find atomic weights.)

4. The formula for ammonia is NH_3. What percent (by weight) of the compound is represented by nitrogen? What percent is represented by hydrogen? (Use the periodic table in appendix B of the text to find atomic weights.)

5. The percent by weight for each of the elements present in $CaSO_4$ is Ca = 29.4%; S = 23.6%; O = 47%. If you had 150 lb of $CaSO_4$, how many pounds of each element would you have?

6. How many pounds of calcium, carbon, and oxygen are there in 60 lb of pure calcium carbonate? (Use the periodic table in appendix B of the text to find atomic weights.)

7. What is the molecular weight for each of the four terms in the following equation. (Use the periodic table in appendix B of the text to find atomic weights.)

$$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$$

8. The equation for the reaction between calcium hypochlorite ($Ca_2(OCl)_2$) and sodium carbonate (Na_2CO_3) is

$$Ca(OCl)_2 + Na_2 \rightarrow 2NaOCl + CaCO_3$$

9. If 20 lb of $Ca(OCl)_2$ are to be used in the reaction, how many pounds of Na_2CO_3 will be used? (Molecular weights: $Ca(OCl)_2$ = 142.98; Na_2CO_3 = 105.99; NaOCl = 74.44; $CaCO_3$ = 100.09.)

10. Find the weight in grams of each of the following:

    a. 0.015 mol sodium arsenite, $NaAsO_2$

    b. 2.5 mol zinc sulfate, $ZnSO_4$

    c. 0.001 mol potassium chloroplatinate, K_2PtCl_6

11. What is the percent of fluoride ion in hydrofluosilicic acid (H_2SiF_6)?

    Note that: H = 1 Si = 28 F = 19

12. What is the percent of fluoride ion in sodium fluoride (NaF)?

    Note that: Na = 23 F = 19

13. What is the percent of fluoride ion in sodium fluorosilicate (Na_2SiF_6)?

    Note that: Na = 23 Si = 28 F = 19

ADDITIONAL NOTES

CHEMISTRY 4

Solutions

OBJECTIVES

After completing study of this chapter, you should understand:

- the principles of creating chemical solutions
- how to calculate quantities of chemicals to use in making chemical solutions
- why chemical solutions are important in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Chemistry 4, Solutions.

OTHER ASSIGNMENTS

CLASS NOTES

1. Terms and definitions:

2. Milligrams per liter and grains per gallon:

3. Percent strength:

4. Equivalent weights and normality:

5. Hardness:

6. Nitrogen compounds:

7. Standard solutions:

REVIEW QUESTIONS

1. If 38 lb of chemical are added to make a solution of 152 lb with water, what is the percent strength of the solution?

2. In 180 gal of solution, there are 60 lb of a certain chemical. What is the percent strength of this solution? Assume the solution has the same density as water— 8.34 lb/gal.

3. You are asked to prepare 160 L of a 3 percent strength solution. How many kilograms of chemical will need to be dissolved in the solution?

4. What volumes of a 2 percent and a 5 percent solution must be mixed to make 250 gal of a 2.5 percent solution?

5. How many pounds of a 6 percent solution and water should be mixed to obtain 150 lb of a 5 percent solution?

6. If 93 g of calcium hydroxide ($Ca(OH)_2$) are used in making a solution, how many moles have been used? (Use the periodic table in appendix B in the *Basic Science Concepts and Applications* text for atomic weights.)

7. If 0.7 mol of H_2SO_4 are dissolved in 820 mL of solution, what is the molarity of the solution?

8. If 75 g of NaOH are dissolved in 700 mL of solution, what is the molarity of the solution? (The molecular weight of NaOH is 40.00.)

9. You are asked to make 600 mL of a 1.8*M* solution of Na_2CO_3. (The molecular weight of Na_2CO_3 is 105.99.)

   a. How many moles of Na_2CO_3 will have to be dissolved in the 600-mL solution?

   b. How many grams of Na_2CO_3 does this equal?

10. If 70 g of NaOH are used in making a solution, how many equivalent weights of NaOH are used in making the solution? (Use 40.00 g for the equivalent weight of NaOH.)

11. If 3 equivalent weights of H_2CO_3 have been used in making 2.5 L of solution, what is the normality of the solution?

12. If 120 g of NaCl are used in making 900 mL of solution, what is the normality of the solution? (Use 58.44 g for the equivalent weight of NaCl.)

13. The water at your treatment plant was analyzed for nitrates. If the nitrate concentration is reported to be 38 mg/L as nitrate, what is the concentration as nitrogen? (The atomic weight of nitrogen is 14.01, and the molecular weight of nitrate is 62.01.)

14. Laboratory test results indicate that the magnesium concentration of a water sample is 70 mg/L as magnesium. What is the magnesium concentration expressed as $CaCO_3$? (Use 12.16 g for the equivalent weight of magnesium, and use 50.00 g for the equivalent weight of calcium.)

15. How much water should be added to 150 mL of a 0.5*N* solution of H_2SO_4 to produce a 0.2*N* solution of H_2SO_4?

16. It takes 43 mL of a 1.5*N* solution of NaOH to react with (neutralize) 25 mL of a certain acid solution. What is the normality of the acid solution?

ADDITIONAL NOTES

CHEMISTRY 5

Acids, Bases, and Salts

OBJECTIVES

After completing study of this chapter, you should understand:

- the meaning and significance of salts, pH, and alkalinity
- why these compounds and measurements are important in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Chemistry 5, Acids, Bases, and Salts.

OTHER ASSIGNMENTS

CLASS NOTES

1. Inorganic compounds are acids, bases, or salts:

2. Acids:

3. Bases:

4. Salts:

5. pH:

6. Alkalinity:

REVIEW QUESTIONS

1. What are the three main groups of inorganic compounds?

2. List four features that distinguish acids.

3. List four features that distinguish bases.

4. Define the term *salts*.

5. What characteristic distinguishes …

   a. a strong acid from a weak acid?

   b. a strong base from a weak base?

6. Write the chemical formulas for the dissociation of one acid and one base.

7. Answer the following questions pertaining to pH:

   a. What is the range of the pH scale?

   b. What range of pH indicates an acidic solution?

   c. What range of pH indicates a basic solution?

   d. What is the pH of pure water?

8. Define the term *alkalinity.*

9. What three types of alkalinity are most commonly found in water treatment, and what ion causes each type?

ADDITIONAL NOTES

CHEMISTRY 6

Chemistry of Treatment Processes

OBJECTIVES

After completing study of this chapter, you should understand:

- taste-and-odor removal processes
- coagulation processes
- iron-and-manganese removal processes
- lime–soda ash softening processes
- recarbonation processes
- ion exchange softening processes
- scale and corrosion control processes
- chlorination processes

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Chemistry 6, Chemistry of Treatment Processes.

OTHER ASSIGNMENTS

CLASS NOTES

1. Taste-and-odor removal:

2. Coagulation:

3. Iron-and-manganese removal:

4. Lime–soda ash softening:

5. Recarbonation:

6. Ion exchange softening:

7. Scale and corrosion control:

8. Chlorination:

REVIEW QUESTIONS

1. What two forms of free available chlorine residual are produced when chlorine is added to pure water? Give their names and chemical abbreviations.

2. Give the names and chemical abbreviations for the three common types of combined chlorine residual.

3. List two differences between free available chlorine residual and combined chlorine residual.

4. List three troublesome chemical characteristics of water that can be removed by chlorination.

5. What materials may be used as sources of chlorine?

6. What is the most active disinfecting compound produced when a hypochlorite is mixed with water?

7. List three common methods of oxidizing iron and manganese.

8. What pH ranges are most effective for iron-and-manganese removal by aeration?

9. What range of $KMnO_4$ dosage is effective for most taste-and-odor removal?

10. What is the most commonly used chemical for coagulation?

11. What is the common range of dosages and the pH operating range for ferric sulfate?

12. What is the most effective pH range for aluminum sulfate?

13. List two advantages and two disadvantages of using ferric sulfate compared with aluminum sulfate.

14. How are the quantities of residuals generated by coagulation with alum calculated?

15. What are the two chemicals used in chemical softening? Give their names and chemical formulas.

16. What are the two general types of hardness? Give examples of each.

17. Which type of hardness is treated with soda ash?

18. At what pH values do $CaCO_3$ and $Mg(OH)_2$ precipitate?

19. List four chemical methods used for scale control.

20. List three methods used for corrosion control.

21. What does a Langelier saturation index of +2.1 mean?

22. What does a Langelier saturation index of –0.9 mean?

23. What does a Langelier saturation index of zero mean?

24. What is chelation and how does it work?

25. How is controlled $CaCO_3$ scaling used in scale and corrosion control?

26. Softening is one technique used to control scaling. List the four major water characteristics that control the tendency for hardness to precipitate and form scale.

27. Define the term *ion exchange*.

28. Name and describe the most commonly used ion exchange resin.

29. How many sodium ions are needed to exchange with one calcium or magnesium ion?

30. How are cation ion exchange resins regenerated?

31. What are the lowest practical hardnesses achieved by lime–soda ash softening and ion exchange softening?

32. Is it desirable to produce zero hardness water? Why?

33. What is recarbonation, and what purpose does it serve?

34. Where in the plant is recarbonation commonly practiced?

35. Describe what occurs if too much CO_2 is added to remove excess lime.

ADDITIONAL NOTES

CHEMISTRY 7

Chemical Dosage Problems

OBJECTIVES

After completing study of this chapter, you should understand chemical dosage problems, including:

- milligrams-per-liter to pounds-per-day conversions
- milligrams-per-liter to percent conversions
- feed rate conversions
- chlorine dosage, demand, and residual calculations
- percent strength calculations
- solution dilution calculations
- reading nomographs

Specific calculations also detailed in the chapter include:

- lime–soda ash softening calculations
- recarbonation calculations
- ion exchange softening calculations
- fluoridation calculations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Chemistry 7, Chemical Dosage Problems.

OTHER ASSIGNMENTS

CLASS NOTES

1. Milligrams-per-liter to pounds-per-day conversions:

2. Milligrams-per-liter to percent conversions:

3. Feed rate conversions:

4. Calculations for chlorine dosage, demand, and residual:

5. Lime–soda ash softening calculations:

6. Recarbonation calculations:

7. Ion exchange softening calculations:

8. Fluoridation calculations:

REVIEW QUESTIONS

Milligrams per Liter to Pounds per Day Conversions

1. The dry alum feed rate at a treatment plant is 380 lb/d. The alum is added to a plant flow of 3,250,000 gpd (gallons per day). What is the alum dosage expressed in milligrams per liter?

2. At a water treatment plant, chlorine is fed at the rate of 3.5 mg/L. The flow at the plant is 4.5 mgd (million gallons per day). How many pounds per day of chlorine are added?

3. Alum is dosed at a rate of 2.2 mg/L, with a plant flow of 750,000 gpd. How many pounds per day of alum are required?

4. On one day, the coagulation process at a plant was operated for 10 hours. During that period, the flow rate through the coagulation process was 250 gpm (gallons per minute). If 45 lb of alum were fed into the water, what was the alum dosage, in milligrams per liter, during the period?

5. To disinfect a water supply, 25 lb/d of chlorine are required. If a commercially available sodium hypochlorite (15 percent available chlorine) is to be used for disinfection, how many pounds per day of sodium hypochlorite will be required?

6. How many pounds of hypochlorite (65 percent available chlorine) are required to disinfect 1,500 ft of 8-in. water line if an initial dose of 45 mg/L is required?

Milligrams per Liter to Percent Conversions

7. Express 150 mg/L as a percent.

8. What is 35,000 mg/L expressed as a percent concentration?

9. A sludge has a total solids concentration of 3.25 percent. What is the concentration expressed as milligrams per liter of solids?

Feed Rate Conversions

10. The feed rate for a chemical is 180 lb/d. What is the feed rate in pounds per hour?

11. The desired feed rate is 28 gpd. What is the feed rate in pounds per hour?

Chlorine Dosage, Demand, and Residual Calculations

12. A water is tested and found to have a chlorine demand of 4.7 mg/L. The desired chlorine residual is 0.3 mg/L. How many pounds of chlorine will be required daily to chlorinate a flow of 3.5 mgd?

13. The water at a plant is dosed with 7.2 mg/L chlorine. The chlorine residual after 30 min of contact time is 0.4 mg/L. What is the chlorine demand expressed in milligrams per liter?

Lime–Soda Ash Softening Calculations

14. Express the following laboratory test results as $CaCO_3$:

Calcium	=	120 mg/L as Ca
Magnesium	=	30 mg/L as Mg
Bicarbonate alkalinity	=	255 mg/L as HCO_3
Total alkalinity	=	215 mg/L as $CaCO_3$
Carbon dioxide	=	15 mg/L as CO_2

15. The laboratory returned the results listed here. Determine how much lime is needed and, if required, how much soda ash is needed to soften this water. Assume no excess lime or soda ash is to be added. Express results as $CaCO_3$. Use the conventional method to solve the problem.

Calcium	=	60 mg/L as Ca
Total hardness	=	175 mg/L as $CaCO_3$
Bicarbonate alkalinity	=	160 mg/L as HCO_3
Total alkalinity	=	140 mg/L as $CaCO_3$
Carbon dioxide	=	10 mg/L as CO_2

16. Express the answers to question 15 as lime and as soda ash.

17. Using 94 percent pure quicklime and 100 percent soda ash, how many pounds per day of chemicals will be needed in question 16 if the flow rate is 2 mgd?

18. A raw-water sample tested as follows:

Total hardness	=	238 mg/L as $CaCO_3$
Calcium	=	70 mg/L as Ca
Magnesium	=	15 mg/L as Mg
Bicarbonate alkalinity	=	160 mg/L as HCO_3
Carbon dioxide	=	9 mg/L as CO_2

On the day the sample was drawn, the plant flow averaged 0.92 mgd. How many pounds of 89 percent pure quicklime (as CaO) and 100 percent pure soda ash (as Na_2CO_3) should have been used that day if an excess of 19 mg/L lime was added? Use the conventional method to solve the problem.

19. Based on the following hardness data, calculate the lime and soda ash require-ments, in pounds per day, for complete removal at an average daily flow rate of 2.18 mgd. Excess lime is added at the rate of 21 mg/L as $CaCO_3$. The soda ash used is 100 percent pure. The quicklime is 90 percent pure. Use the conversion factor method and Table C7–3 in the *Basic Science Concepts and Applications* text.

Total hardness	=	192 mg/L as $CaCO_3$
Mg	=	12 mg/L as Mg
HCO_3^-	=	167 mg/L as $CaCO_3$
CO_2	=	18 mg/L as CO_2
Total alkalinity	=	167 mg/L as $CaCO_3$

Recarbonation Calculations

20. The following results of water quality analyses were reported for treated water. Calculate the correct CO_2 dosage. Results of the analyses are given in mg/L as $CaCO_3$.

	For Raw Water	After Lime–Soda Ash Treatment	Desired After Recarbonation
Bicarbonate alkalinity	250	0	5
Carbonate alkalinity	0	35	20
Hydroxide alkalinity	0	50	0

Ion Exchange Softening Calculations

21. An ion exchange water softener unit holds cationic polystyrene resin and has these operating features:

Bed depth	= 26 in.
Loading rate	= 4.8 gpm/ft^2
Brine strength	= 12.9% (1.24 lb/gal)
Surface area	= 4.1 ft^2
Volume of exchange material	= 8.88 ft^3
Rated removal capacity	= 30,000 grains/ft^3
Average water hardness	= 142 mg/L
Salt regeneration requirement	= 0.35 lb salt/1,000 grains of hardness removed

Calculate the following:

a. total removal capacity

b. volume treated per cycle

c. softening run lengths in hours

d. pounds of salt needed for regeneration

e. gallons of brine needed for regeneration

Fluoridation Calculations

22. Calculate the percentage of fluoride by weight in each of the three commonly used fluoride compounds—sodium fluoride (NaF), sodium fluorosilicate (Na_2SiF_6), and fluosilicic acid (H_2SiF_6). (Use the following atomic weights: sodium = 23; fluorine = 19; silica = 28; and hydrogen = 1.)

23. The purity of a 50-kg bag of NaF is labeled “96 percent.” How many kilograms of fluoride ion are contained in the bag of NaF? (Use NaF information calculated in question 22.)

24. Fluoridation is accomplished by direct addition of fluosilicic acid, as delivered. The strength of the acid is 32 percent, and the density is 11.1 lb/gal. How many gallons of acid are needed daily to fluoridate 0.16 mgd to a level of 1 mg/L? (Use H_2SiF_6 data calculated in question 22.)

25. A water is fluoridated using a saturated solution of NaF, 95 percent pure. The density of the solution is about 8.6 lb/gal. How many gallons per day of the solution would be needed to fluoridate 0.16 mgd to a level of 1 mg/L?

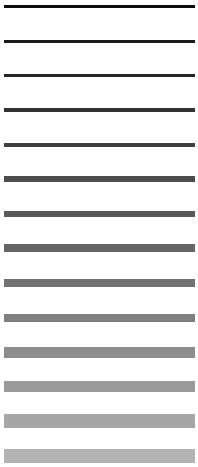
26. How much sodium fluorosilicate (98.5 percent pure) is needed to treat a 6.4-mgd flow to a level of 1.2 mg/L if the natural fluoride concentration is 0.3 mg/L?

27. How much water at 15.6°C is needed to dissolve 80 lb of Na_2SiF_6? (The solubility of Na_2SiF_6 is 0.65 g/100 mL at 15.6°C.)

28. What gallons-per-minute feed rate should be used to deliver the solution in question 27 uniformly over a 24-hour period?

ADDITIONAL NOTES

Electricity



Electricity, Magnetism, and Electrical Measurements

OBJECTIVES

After completing study of this chapter, you should understand:

- basic electricity, magnetism, and electrical measurements and terms
- why a knowledge of electricity is important for water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Electricity 1, Electricity, Magnetism, and Electrical Measurements.

OTHER ASSIGNMENTS

CLASS NOTES

1. Electricity and magnetism:

2. Electrical measurements and equipment:

REVIEW QUESTIONS

1. Electricity is the study of _____.
2. What is static electricity?

3. What is dynamic electricity?

4. What are the two types of force that determine the movement of electrons?

5. Define the terms *direct current* and *alternating current*.

6. Give three examples of electromagnetic waves.

7. What are the units of measurement of electrical potential and electrical current?

8. For each of the following hydraulic concepts or mechanisms, list the comparable electrical concept or device:

   a. pressure

   b. flow rate

   c. friction

   d. pump

   e. reservoir

   f. turbine-driven pump

   g. flooding

ADDITIONAL NOTES

Electrical Quantities and Terms

OBJECTIVES

After completing study of this chapter, you should understand:

- basic electrical quantities and terms
- why electrical quantities and terms are important in water system operations

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Electricity 2, Electrical Quantities and Terms.

OTHER ASSIGNMENTS

CLASS NOTES

1. Alternating current:

2. Ampere and ampere-hour:

3. Apparent power:

4. Capacitance and capacitors:

5. Cycle:

6. Demand:

7. Direct current:

8. Energy:

9. Frequency:

10. Ground:

11. Impedance:

12. Inductance:

13. Interrupting current:

14. Inverter:

15. Kilovar:

16. Kilovolt:

17. Kilowatt and kilowatt-hour:

18. Kilovolt-ampere:

19. Maximum demand:

20. Megohm, ohm:

21. Phase:

22. Pole:

23. Power:

24. Power factor:

25. Primary:

26. Rating:

27. Reactance:

28. Real power:

29. Resistance:

30. Safety factor:

31. Secondary:

32. Substation:

33. Transformer:

34. Volt:

35. Watt and watt-hour:

REVIEW QUESTIONS

1. Current in a system starts at zero voltage, rises to a maximum, returns to zero, increases to a maximum in the opposite direction, and returns again to zero; it repeats this 60 times each second. What is the term applied to this current?

2. How much current would flow through a resistance of 1 ohm when the voltage across the resistance is 1 V?

3. A battery can deliver 25 A for 6 hours; what is the battery's rating?

4. How is apparent power expressed in units?

5. What device is sometimes used to prevent a sudden rise in voltage?

6. Define the term *demand*.

7. How is electric energy expressed?

8. What are the two types of charges usually shown on power bills?

9. What is the frequency of the alternating current used by most US distribution systems?

10. What is the name for an electrical connection to earth or to a large conductor known to be at the same potential as earth?

11. Define the term *impedance* and list the three parts that make up impedance.

12. What does the prefix *kilo* mean?

13. What is measured in kilovars?

14. What is measured in ohms? Define the term *ohm* in terms of volts and amperes.

15. Are larger load applications usually single-phase or three-phase?

16. How many wires are required for a single-phase system? How many are required for a three-phase system?

17. An 18-kVA (kilovolt-amperes) motor is running at a 0.8 power factor. How many kilowatts of real power is it drawing?

18. Define the term *power*. How is it measured in electrical systems?

19. What is the high-voltage side of a step-down transformer called? What is the low-voltage side called?

20. Resistance causes power losses in the form of _____ produced by the current in the resistor.

21. Reactance is composed of two parts: Name them.

22. What is another word for the term *reactive power*?

23. The safety factor of a motor allows for a slight overload; what will happen if the motor is operated continuously at this slight overload?

24. What is the electric potential needed to send a current of 1 A through a resistance of 1 ohm?

ADDITIONAL NOTES

Functions and Ratings of Electrical Equipment

OBJECTIVES

After completing study of this chapter, you should understand the basic function and ratings of electrical equipment used in water systems.

READING ASSIGNMENT

Basic Science Concepts and Applications: Read Electricity 3, Functions and Ratings of Electrical Equipment.

OTHER ASSIGNMENTS

CLASS NOTES

1. Functions of electrical equipment:

2. Rating electrical materials and equipment:

REVIEW QUESTIONS

1. Define the term *preventive maintenance*.

2. What is used to produce large amounts of alternating current?

3. Generally, onsite generation of electric power at water utilities is used only for _____.

4. List five types of prime movers used with generators.

5. What are the two basic electrical devices used to store electricity?

6. In a storage battery, the chemical reactions that produce electricity are almost completely reversible. What practical meaning does this have?

7. What is an important safety consideration when charging batteries?

8. What is one of the most common uses of a transformer?

9. Define the terms *rectifier* and *inverter.*

10. What are two types of instrument transformers?

11. Identify factors involved in the maintenance of overhead transmission lines. Who should be authorized to perform line work?

12. What are two types of equipment found in every incoming feeder installation?

13. Wherever more than one incoming feeder is used, equipment is needed to automatically switch from one feeder to another. This switching equipment is referred to as _____ equipment.

14. What is a radial distribution system?

15. What are two devices used to protect circuits?

16. Name the instruments used to measure the following:

    a. electrical potential

    b. current

    c. real power

    d. unreal power

e. average power of a load during some specific time interval

f. electric energy

g. ratio of real power to apparent power

h. frequency

17. Electric energy is usually converted to another form of energy for use in industry or the home. List five types of energy that it may be converted to, and name the device involved in the conversion.

18. What four ratings describe the applicability of a fuse?

19. In general, which is larger; a molded-case circuit breaker or a power circuit breaker?

20. What is the term for a substance that allows the passage of electricity with great ease? What is the term for a substance that offers very great resistance to the flow of electricity?

21. In what units is resistance measured? In what units is conductance measured?

22. Identify two causes of insulation failure.

23. Can a fuse holder be used with a fuse of a higher or a lower rating than the rating of the holder?

24. Identify two functions of a circuit breaker.

25. What is the maximum voltage rating in which molded-case-type circuit breakers are available?

26. What measure is used for the interrupting capacity of high-voltage switchgear?

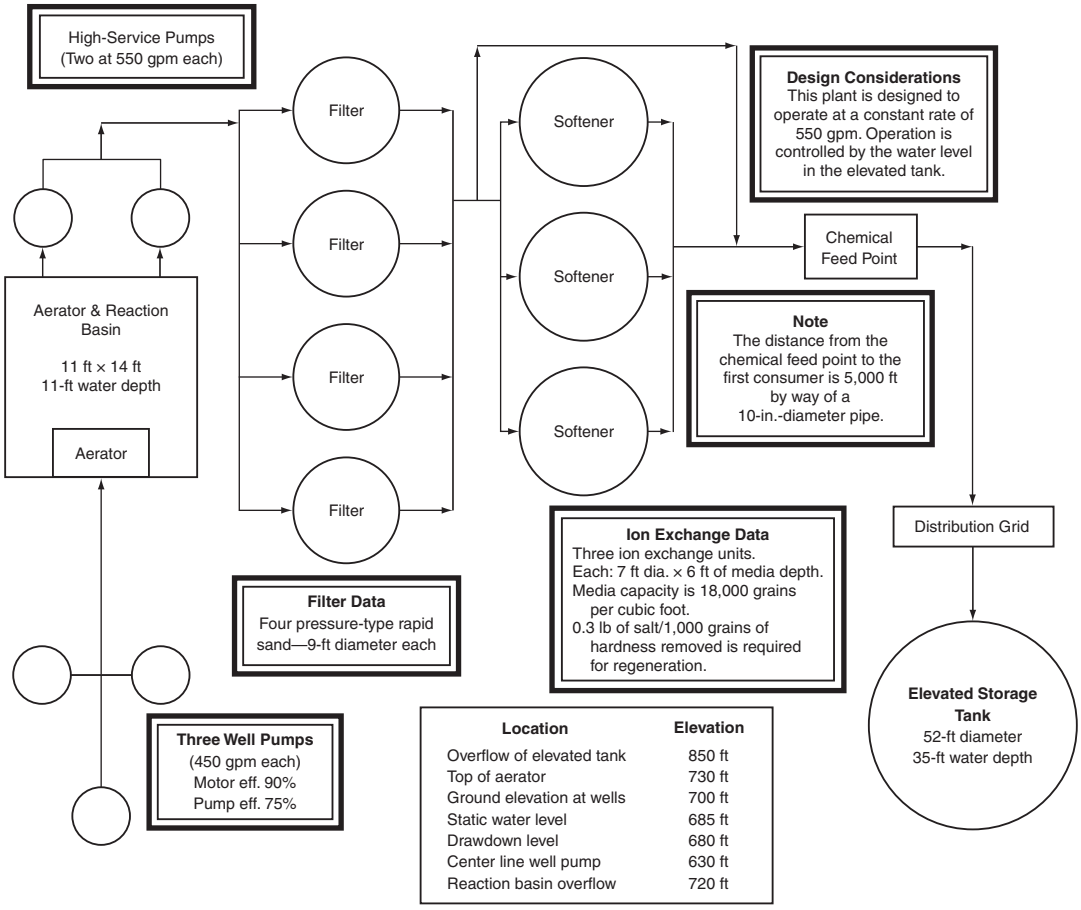
ADDITIONAL NOTES

Sample Plant Diagrams and Questions

Ion Exchange and Lime–Soda Ash Softening Plants

The following plant diagrams and related questions test your cumulative knowledge of math, hydraulics, and chemistry. An answer key follows each section.

ION EXCHANGE PLANT 1


High-Service Pumps
(Two at 550 gpm each)
Filter
Filter
Filter
Filter
Softener
Softener
Softener
Design Considerations
This plant is designed to operate at a constant rate of 550 gpm. Operation is controlled by the water level in the elevated tank.
Chemical Feed Point
Note
The distance from the chemical feed point to the first consumer is 5,000 ft by way of a 10-in.-diameter pipe.
Aerator & Reaction Basin
11 ft × 14 ft
11-ft water depth
Aerator
Distribution Grid
Ion Exchange Data
Three ion exchange units.
Each: 7 ft dia. × 6 ft of media depth.
Media capacity is 18,000 grains per cubic foot.
0.3 lb of salt/1,000 grains of hardness removed is required for regeneration.
Filter Data
Four pressure-type rapid sand—9-ft diameter each
Elevated Storage Tank
52-ft diameter
35-ft water depth
Three Well Pumps
(450 gpm each)
Motor eff. 90%
Pump eff. 75%

Location	Elevation
Overflow of elevated tank	850 ft
Top of aerator	730 ft
Ground elevation at wells	700 ft
Static water level	685 ft
Drawdown level	680 ft
Center line well pump	630 ft
Reaction basin overflow	720 ft

Chemicals used per month (30 d/month)

Plant tap chlorine residuals:
Free 1.2 mg/L; combined 0.1 mg/L; 3 softeners in service
Chlorine 275 lb
Soda ash 956 lb
Raw-water iron (Fe) 1.6 mg/L
Raw-water manganese (Mn) 78 µg/L
Raw-water hardness 335 mg/L
Raw-water alkalinity 305 mg/L

Plant production: 0.651 mgd

Finished water hardness 153 mg/L
Finished water alkalinity 310 mg/L
Finished water iron (Fe) 0.16 mg/L
Finished water manganese (Mn) 20 µg/L

Softeners:	Number of regenerations—65; metered softener rinse & wash water—256,750 gal/month
Brine:	36% (3.6 lb of salt/gal of brine); 3 softeners in service
Filters:	Number of filters—4; number of backwashes—63; filter bashwash water—457,380 gal/month
Backwashes:	15 min each; chlorine—275 lb/month; soda ash—956 lb/month
Raw-water data:	10-in.-diameter main; hardness 335 mg/L; alkalinity 305 mg/L
Finished water data:	Hardness 153 mg/L; alkalinity 310 mg/L

ION EXCHANGE PLANT 1 QUESTIONS (Answers on page 250)

1. What is the water horsepower of each well pump?

2. What is the brake horsepower of each well pump?

3. What is the motor horsepower of each well pump?

4. What is the drawdown in feet on the well pumps during operating conditions?

5. What is the suction head on the well pumps during operating conditions?

6. What is the wire-to-water efficiency on the raw-water pumps?

7. What is the detention time in the aeration and reaction basin, in minutes, under design conditions?

8. How many pound of noncarbonate hardness are removed each day during operating conditions?

9. How many amps does the well pump pull at 240 volts single-phase?

10. What is the water horsepower on the high-service pumps?

11. What is the filtration rate on the iron filters under design conditions?

12. How many pounds of iron (Fe) are removed each day under design conditions?

13. How many pounds of manganese (Mn) are removed each month under operating conditions?

14. If only two well pumps run when the aeration basin calls for water, how many hours and minutes per day do the well pumps run under operating conditions?

15. If only two well pumps run when the aeration basin calls for water, what is the velocity in the raw-water main in feet per second?

16. If only two well pumps run when the aeration basin calls for water, what is the flow rate in the raw-water main in cubic feet per second?

17. What is the bypass rate, in gallons per minute, on the softeners under design conditions?

18. What is the exchange capacity of the ion exchange softeners in grains?

19. How many gallons of water of 0.0-mg/L water can the softeners produce before they need to be regenerated under operating conditions?

20. How many gallons of finished water can the softeners produce before they need to be regenerated under operating conditions?

21. How many hours and minutes can the softeners operate before they need to be regenerated?

22. How many pounds of salt will be needed to regenerate one softener?

23. How many pounds of salt will be needed per month under operating conditions?

24. What is the backwash rate, in gallons per minute per square foot, on the filters under operating conditions?

25. What are the inches of rise on the filters during the backwash cycle under operating conditions?

26. How many gallons of brine are needed to regenerate one softener under design conditions?

27. What is the percentage of finished water used for backwashing filters for the month under operating conditions?

28. What is the percentage of finished water used for backwashing filters and regenerating the softeners for the month under operating conditions?

29. What is the soda ash dosage, in milligrams per liter, under operating conditions?

30. What is the chlorine demand under operating conditions?

ANSWERS TO ION EXCHANGE PLANT 1 QUESTIONS

1. 730 ft – 680 ft × 450 gpm ÷ 3,960 = 5.68 whp

2. 730 ft – 680 ft × 450 gpm ÷ (3,960 × 0.75 P.E.) = 7.58 bhp
(2,970)

3. 730 ft – 680 ft × 450 gpm ÷ (3,960 × 0.9 M.E. × 0.75 P.E.) = 8.42 mhp
(2,673)

4. 685 ft – 680 ft = 5 ft

5. 680 ft – 630 ft = 50 ft

6. 5.68 whp ÷ 8,42 mhp × 100 = 67.46% w to w *or* 0.9 M.E. × 0.75 P.E. × 100 = 67.5% w to w

7. 11 ft × 11 ft × 14 ft × 7.48 gal/ft^3 ÷ 550 gpm = 23 min

8. 335 mg/L – 305 mg/L × 0.651 mgd × 8.34 lb/d = 162.9 lb/d

9. 8.42 mhp × 746 whp ÷ 240 V = 26.17 amps

10. 850 ft – 720 ft × 550 gpm ÷ 3,960 = 18.06 whp

11. (0.792 mgd × 1,000,000 gal/MG ÷ 24 h/d ÷ 60 min/h) ÷ (4.5 ft × 4.5 ft × 3.14 × 4 units) = 2.16 gpm/ft^2
(550 gpm) (254.3 ft^2)

12. (550 gpm × 60 min/h × 24 h/d ÷ 1,000,000 gal/MG) × 8,34 lb/gal × (1.6 mg/L – 0.16 mg/L) = 9.51 lb/d
(0.792 mgd) (1.44 mg/L)

13. (0.651 mgd × 30 d/month) × 8,34 lb/gal × (0.078 mg/L – 0.020 mg/L) = 9.45 lb/month
(19.53 MG/month) (0.058 mg/L)
[78 µg/L ÷ 1,000 µg/L/mg/L = 0.078 mg/L]

14. 0.651 mgd × 1,000,000 gal/MG ÷ (450 gpm × 2 units × 60 min/h) = 12.06 h *or* 12 h 4 min
(54,000 gal/h)
[0.06 h × 60 min/h = 3.6 min]

15. 900 gpm ÷ 60 s/min ÷ 7.48 gal/ft^3 ÷ (0.417 ft × 0.417 ft × 3.14) = 3.67 fps

16. 900 gpm ÷ 60 s/min ÷ 7.48 gal/ft^3 = 2.01 cfs

17. 550 gpm × 0.457 = 251.35 gpm bypassed
335 mg/L – 153 mg/L ÷ 335 mg/L × 100 = 54.3% softened
100% – 54.3% = 45.7% bypassed *or* 153 mg/L ÷ 335 mg/L × 100 = 45.7% bypassed

18. 3.5 ft × 3.5 ft × 3.14 × 6 ft × 3 units × 18,000 gr/ft^3 = 12,462,660 gr

19. 12,462,660 gr ÷ (335 mg/L ÷ 17.1 mg/L/gpg) = 636,174.6 gal
(19.59 gpg)

20. 12,462,660 gr ÷ (335 mg/L – 153 mg/L ÷ 17.1 mg/L/gpg) = 1,171,302 gal
(10.64 gpg)

21. 636,174.6 gal ÷ 298.65 gpm ÷ 60 min/h = 35.5 h or 35 h 30 min
[550 gpm – 251.35 gpm bypassed = 298.65 gpm softened] *or*

1,171,302.6 gal ÷ 550 gpm ÷ 60 min/h = 35.5 h or 35 h 30 min
[0.5 h × 60 min/h = 30 min]

22. 3.5 ft × 3.5 ft × 3.14 × 6 ft × 18,000 gr/ft^3 ÷ 1,000 × 0.3 lb salt = 1,246.27 lb salt per regeneration

23. 1,246.27 lb salt/regeneration × 65 regenerations/month = 81,077.6 lb salt/month

24. 457,380 gal/month ÷ 63 washes/month ÷ 15 min/backwash ÷ (3.5 ft × 3.5 ft × 3.14) = 12.6 gpm/ft^2
(38.5 ft^2)

25. 12.6 gpm/ft^2 × 1.6 in. of rise/gpm/ft^2 = 20.2 in. of rise

26. 1,246.27 lb salt ÷ 3.6 lb salt/gal = 346.2 gal

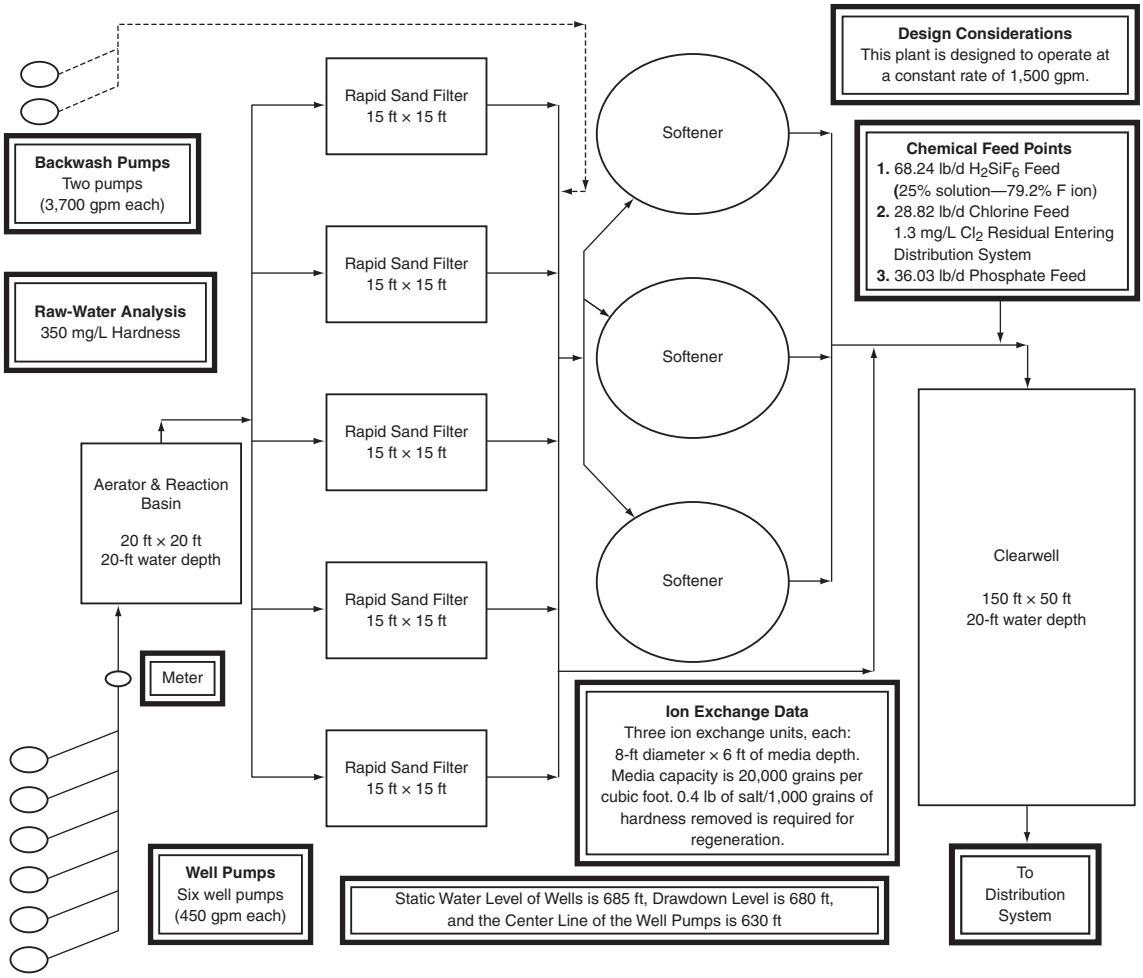
27. 100% – [(0.651 mgd × 1,000,000 gal/MG × 30 d/month) – (457,380 gal/month)
÷ (0.651 mgd × 1,000,000 gal/MG × 30 d/month) × 100] = 2.34%
(19,530,000 gal/month) (19,530,000 gal/month)

28. 100% – [(0.651 mgd × 1,000,000 gal/MG × 30 d/month) – (457,380 gal/month)
+ 256,750 gal/month) ÷ (0.651 mgd × 1,000,000 gal/MG × 30 d/month) × 100] = 3.66%
(19,530,000 gal/month) (19,530,000 gal/month)

29. 956 lb/month ÷ 30 d/month ÷ 0.651 mgd ÷ 8.34 lb/gal = 5.8 mg/L

30. 275 lb/month ÷ 30 d/month ÷ 0.651 mgd ÷ 8.34 lb/gal – (1.2 mg/L – 0.1 mg/L) = 0.39 mg/L
or 0.4 mg/L

ION EXCHANGE PLANT 2


Design Considerations
This plant is designed to operate at a constant rate of 1,500 gpm.
Backwash Pumps
Two pumps
(3,700 gpm each)
Raw-Water Analysis
350 mg/L Hardness
Rapid Sand Filter
15 ft × 15 ft
Rapid Sand Filter
15 ft × 15 ft
Rapid Sand Filter
15 ft × 15 ft
Rapid Sand Filter
15 ft × 15 ft
Rapid Sand Filter
15 ft × 15 ft
Softener
Softener
Softener
Chemical Feed Points
1. 68.24 lb/d H_2SiF_6 Feed
(25% solution—79.2% F ion)
2. 28.82 lb/d Chlorine Feed
1.3 mg/L Cl_2 Residual Entering Distribution System
3. 36.03 lb/d Phosphate Feed
Aerator & Reaction Basin
20 ft × 20 ft
20-ft water depth
Meter
Clearwell
150 ft × 50 ft
20-ft water depth
Ion Exchange Data
Three ion exchange units, each: 8-ft diameter × 6 ft of media depth. Media capacity is 20,000 grains per cubic foot. 0.4 lb of salt/1,000 grains of hardness removed is required for regeneration.
Well Pumps
Six well pumps
(450 gpm each)
Static Water Level of Wells is 685 ft, Drawdown Level is 680 ft, and the Center Line of the Well Pumps is 630 ft
To Distribution System

ION EXCHANGE PLANT 2 QUESTIONS (Answers on page 256)

1. What is the reaction time, in minutes, in the reaction tank when two well pumps are on?

2. If each rapid sand filter is backwashed at 3,500 gpm (gallons per minute), what is the backwash rate in gallons per minute per square foot?

3. Calculate the suction head, in feet, on the well pump.

4. What is the drawdown, in feet, of the well pump?

5. Calculate the filtration rate, in gallons per minute per square foot, of the five rapid sand filters at design flow.

6. What is the hardness removal capacity, in grains removal, of each ion exchange unit?

7. How many million gallons per day can be produced at design capacity?

8. How much water at 350 mg/L hardness can be passed through each ion exchange unit before it is necessary to regenerate?

9. What is the capacity, in gallons, of the clearwell?

10. What total quantity, in gallons, of "zero" hardness water will be produced by the plant between regenerations?

11. What quantity of salt, in pounds, will be needed to regenerate one unit?

12. Under design conditions, what rate, in gallons per minute per square foot, are the three softening units loaded?

13. A test is conducted to check the accuracy of the filter rate of flow controllers. It is a 5-min test and the water dropped 12 in. What is the filtration rate in gallons per minute?

14. Only considering the rapid sand filters, what is the maximum operating flow, in million gallons per day, the plant can produce with one filter out of service and a filter loading rate of 2 gpm/ft^2?

15. A fluoride analysis of the water entering the distribution system is 1.00 mg/L. What is the fluoride content of the raw water in milligrams per liter?

16. What is the chlorine demand in milligrams per liter?

17. What is the phosphate residual in milligrams per liter?

18. How much water should be bypassed around the ion exchange softeners, in gallons per minute, when the finished water hardness if 8 gpg (grains per gallon) and the raw-water hardness is 350 mg/L?

19. What is the percent bypass water?

ANSWERS TO ION EXCHANGE PLANT 2 QUESTIONS

1. $\text{reaction time} = \dfrac{\text{volume}}{\text{flow rate}}$

$\text{volume} = 20 \text{ ft} \times 20 \text{ ft} \times 20 \text{ ft} \times 748 \text{ gal/ft}^3 = 59{,}840 \text{ gal}$

$\text{flow rate} = 450 \text{ gpm} \times 2 = 900 \text{ gpm}$

$\text{reaction time} = \dfrac{59{,}840 \text{ gal}}{900 \text{ gpm}}$

$\text{reaction time} = 66.5 \text{ min } \textit{or } 1 \text{ hr } 6.5 \text{ min}$

2. $\text{backwash rate} = \dfrac{\text{gpm}}{\text{ft}^2}$

$\text{ft}^2 = 15 \text{ ft} \times 15 \text{ ft} = 225 \text{ ft}^2$

$\text{backwash rate} = \dfrac{3{,}500 \text{ gpm}}{225 \text{ ft}^2}$

$\text{backwash rate} = 15.6 \text{ gpm/ft}^2$

3. 680 ft – 630 ft = 50 ft suction head lift

4. 685 ft – 680 ft = 5 ft drawdown

5. $\text{filtration rate} = \dfrac{\text{flow (gpm)}}{\text{ft}^2}$

$\text{ft}^2 = 15 \text{ ft} \times 15 \text{ ft} \times 5 \text{ filters} = 1{,}125 \text{ ft}^2$

$\text{filtration rate} = \dfrac{1{,}500 \text{ gpm}}{1{,}125 \text{ ft}^2}$

$\text{filtration rate} = 1.33 \text{ gpm/ft}^2$

6. $\text{softening capacity} = \text{ft}^3 \times \text{gr/ft}^3$

$\text{ft}^3 = 0.785 \times 8 \text{ ft} \times 8 \text{ ft} \times 6 \text{ ft} = 301.44 \text{ ft}^3$

$\text{softening capacity} = 301.44 \text{ ft}^3 \times 20{,}000 \text{ gr/ft}^3$

$\text{softening capacity} = 6{,}028{,}800 \text{ gr/each softener}$

7. plant flow = 1,500 gpm × 1,440 min/day = 2,160,000 gal

8. $\dfrac{350 \text{ mg/L}}{17.1 \text{ mg/L/gpg}} = 20.5 \text{ gpg}$

$\dfrac{6{,}028{,}800 \text{ gr/softener}}{20.5 \text{ gpg}}$ *(from no. 6)* $= 294{,}088 \text{ gal/softener}$

9. $\text{volume} = 150 \text{ ft} \times 50 \text{ ft} \times 20 \text{ ft} \times 7.48 \text{ gal/ft}^3$

$\text{volume} = 1{,}122{,}000 \text{ gal}$

10. 294,088 gal/unit × 3 units = 882,264 gal

11. 6,028,800 gr/unit (*from no. 6*) × 0.4 lb of salt/1,000 gr = 2,411.52 lb/unit

12. softeners loading $= \frac{\text{gpm}}{\text{ft}^2}$

$\text{ft}^2 = 0.785 \times 8 \text{ ft} \times 8 \text{ ft} \times 3 \text{ units} = 150.72 \text{ ft}^2$

softeners loading $= \frac{1{,}500 \text{ gpm}}{150.72 \text{ ft}^2}$

softeners loading $= 9.95 \text{ gpm/ft}^2$

13. $12 \text{ in.} = 1 \text{ ft}$

$15 \text{ ft} \times 15 \text{ ft} \times 1 \text{ ft} \times 5 \text{ units} \times 7.48 \text{ gal/ft}^3 = 8{,}415 \text{ gal}$

$\frac{8{,}415 \text{ gal}}{5 \text{ min}} = 1{,}683 \text{ gpm}$

14. $15 \text{ ft} \times 15 \text{ ft} \times 4 \text{ units} \times 2 \text{ gpm/ft}^2 = 1{,}800 \text{ gpm}$

$1{,}800 \text{ gpm} \times 1{,}440 \text{ min/day} = 2{,}592{,}000 \text{ gal } \textit{or } 2.592 \text{ mgd}$

15. $1{,}500 \text{ gpm} \times 1{,}440 \text{ min/day} = 2{,}160{,}000 \text{ gpd}$

$68.24 \text{ lb/day} \times 0.792 \ (79.2\%) = 54 \text{ lb/day}$

$54 \text{ lb/day} \times 0.25 \ (25\%) = 13.5 \text{ lb/day}$

$\frac{13.5 \text{ lb/day}}{2.16 \times 8.34 \text{ lb/gal}} = 0.75 \text{ mg/L}$

$1 \text{ mg/L} - 0.75 \text{ mg/L} = 0.25 \text{ mg/L fluoride}$

16. $\text{mg/L} = \frac{28.82 \text{ lb}}{2.15 \text{ mgd} \times 8.34 \text{ lb/gal}} = 1.6 \text{ mg/L (dose)}$

$1.6 \text{ mg/L (dosage)} - 1.3 \text{ mg/L (residual)} = 0.3 \text{ mg/L residual}$

17. $\text{mg/L} = \frac{36.03 \text{ lb}}{2.16 \text{ mgd} \times 8.34 \text{ lb/gal}} = 2.0 \text{ mg/L phosphate}$

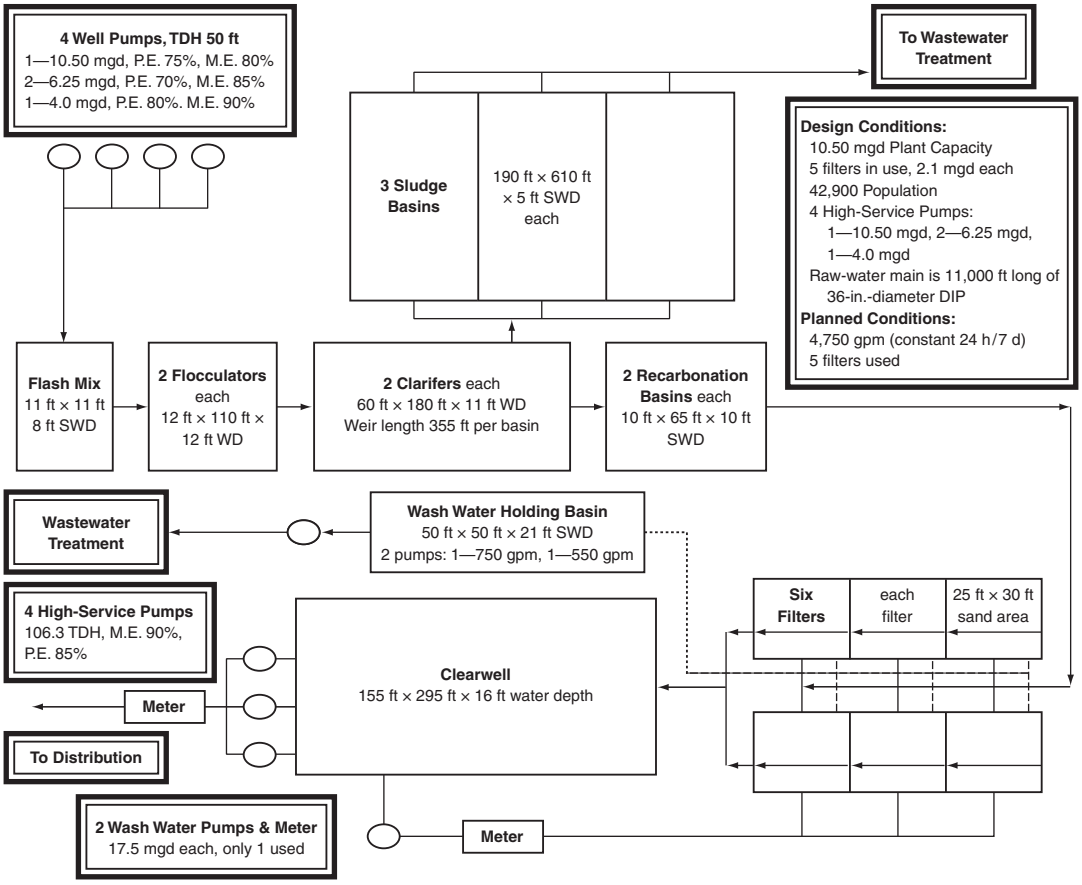
18. $\frac{350 \text{ mg/L}}{17.1 \text{ mg/L/gpg}} = 20.5 \text{ gpg}$

$\frac{8 \text{ gpg}}{20.5 \text{ gpg}} \times 100 = 39\%$

$1{,}500 \text{ gpm} \times 0.39 = 585 \text{ gpm bypassed}$

19. $\frac{8 \text{ gpg}}{20.54 \text{ gpg}} \times 100 = 39\% \text{ bypassed}$

LIME–SODA ASH SOFTENING PLANT


4 Well Pumps, TDH 50 ft
1—10.50 mgd, P.E. 75%, M.E. 80%
2—6.25 mgd, P.E. 70%, M.E. 85%
1—4.0 mgd, P.E. 80%. M.E. 90%
To Wastewater Treatment
3 Sludge Basins
190 ft × 610 ft × 5 ft SWD each
Design Conditions:
10.50 mgd Plant Capacity
5 filters in use, 2.1 mgd each
42,900 Population
4 High-Service Pumps:
1—10.50 mgd, 2—6.25 mgd, 1—4.0 mgd
Raw-water main is 11,000 ft long of 36-in.-diameter DIP
Planned Conditions:
4,750 gpm (constant 24 h/7 d)
5 filters used
Flash Mix
11 ft × 11 ft
8 ft SWD
2 Flocculators each
12 ft × 110 ft × 12 ft WD
2 Clarifers each
60 ft × 180 ft × 11 ft WD
Weir length 355 ft per basin
2 Recarbonation Basins each
10 ft × 65 ft × 10 ft SWD
Wastewater Treatment
Wash Water Holding Basin
50 ft × 50 ft × 21 ft SWD
2 pumps: 1—750 gpm, 1—550 gpm
Six Filters
each filter
25 ft × 30 ft sand area
4 High-Service Pumps
106.3 TDH, M.E. 90%, P.E. 85%
Clearwell
155 ft × 295 ft × 16 ft water depth
Meter
To Distribution
2 Wash Water Pumps & Meter
17.5 mgd each, only 1 used
Meter

30 d/month

Operating conditions:	7.15 mgd	Chlorine used per month:	6,289 lb
Filter washes:	46/month	Tap chlorine:	Free 1.2 mg/L; combined 0.1 mg/L
Wash water used:	5,168,700 gal/month		
Sludge to basins:	3,178,200 gal/month	Distribution chlorine:	Free 0.9 mg/L; combined 0.1 mg/L

LIME–SODA ASH SOFTENING PLANT QUESTIONS (Answers on page 262)

1. What is the water horsepower of the 10.50-mgd (million gallons per day) well pump?

2. What is the brake horsepower of the 6.25-mgd well pump?

3. What is the motor horsepower of the 4.0-mgd well pump?

4. What is the wire-to-water percent efficiency of the 6.25-mgd well pump?

5. What is the detention time in the raw-water main, in hours and minutes, during operating conditions?

6. What is the velocity, in feet per second, in the raw-water main under design conditions?

7. What is the detention time, in seconds, in the flash mix under design conditions?

8. What is the detention time, in minutes and seconds, in the flocculators under design conditions?

9. What is the velocity, in feet per minute, in the flocculators under operating conditions?

10. What is the detention time, in hours and minutes, in the clarifiers under operating conditions?

11. What is the velocity, in feet per minute, in the clarifiers under design conditions?

12. What is the weir overflow rate, in gallons per day per foot, in the clarifiers under planned conditions?

13. What is the surface overflow rate, in gallons per day per square foot, in the clarifers under design conditions?

14. What is the velocity in the recarbonation basins, in feet per minute, under design conditions?

15. What is the detention time, in minutes and seconds, in the recarbonation basins under operating conditions?

16. What is the filter bachwash rate, in gallons per minute per square foot, under design conditions?

17. What is the inches of rise during the backwash cycle under design conditions?

18. What is the percentage of finished water using for filter backwashes under operating conditions?

19. How many backwashes will the wash water holding basin hold with no pumps running?

20. How long, in hours and minutes, will the 750-gpm (gallons per minute) pump take to empty the wash water holding basin if it is full and no filters are being backwashed?

21. What is the detention time, in hours and minutes, in the clearwell under design conditions?

22. What is the detention time, in days, in the sludge basins under operating conditions?

23. What is the chlorine dosage, in milligrams per liter, under operating conditions?

24. What is the chlorine demand, in milligrams per liter, under operating conditions?

ANSWERS TO LIME–SODA ASH SOFTENING PLANT QUESTIONS

1. (10.50 mgd × 1,000,000 gal/MG ÷ 24 h/d ÷ 60 min/h) [7,291.7 gpm] × 50 ft ÷ 3,960 = 92.1 whp

2. (6.25 mgd × 1,000,000 gal/MG ÷ 24 h/d ÷ 60 min/h) [4,340.3 gpm] × 50 ft ÷ (3,960 × 0.70 P.E.) [2,772] = 78.3 bhp

3. (4.0 mgd × 1,000,000 gal/MG ÷ 24 h/d ÷ 60 min/h) [2,777.8 gpm] × 50 ft ÷ (3,960 × 0.80 P.E. × 0.90 M.E.) [2,851.2] = 48.7 mhp

4. 0.70 P.E. × 0.85 M.E. × 100 = 59.5% w to w *or* whp ÷ mhp × 100 % w to w

5. (1.5 ft × 1.5 ft × 3.14 × 11,000 ft × 7.48 gal/ft^3) [581,308 gal] ÷ (7.15 mgd × 1,000,000 gal/MG ÷ 24 h/d) [297,916.7 gph] = 1.95 h or 1 h 57 min
[0.95 h × 60 min/h = 57 min]

6. (10.50 mgd × 1,000,000 gal/MG ÷ 24 h/d ÷ 60 min/h ÷ 60 s/min ÷ 7.48 gal/ft^3) [16.25 cfs]
÷ (1.5 ft × 1.5 ft × 3.14) [7.07 ft^2] = 2.3 fps

7. 11 ft × 11 ft × 8 ft × 7.48 gal/ft^3 ÷ (10.50 mgd × 1,000,000 gal/MG ÷ 24 h/d ÷ 60 min/h ÷ 60 s/min) [121.53 gps] = 59.6 s

8. (12 ft × 110 ft × 12 ft × 7.48 gal/ft^3 × 2 units) [236,966.4 gal] ÷ (10.50 mgd × 1,000,000 gal/MG ÷ 24 h/d ÷ 60 min/h) [7,291.7 gpm] = 32.5 min *or* 32 min 30 s
[0.5 min × 60 s/min = 30 s]

9. (7.15 mgd × 1,000,000 gal/MG ÷ 24 h/d ÷ 60 min/h ÷ 7.48 gpm) [663.8 ft^3/min] ÷ (12 ft × 12 ft × 2 units) [288 ft^2] = 2.3 fpm

10. (60 ft × 180 ft × 11 ft × 7.48 gal/ft^3 × 2 units) [1,777,248 gal] ÷ (7.15 mgd × 1,000,000 gal/MG ÷ 24 h/d) [297,916.7 gph] = 5.97 h *or* 5 h 58 min
[0.97 h × 60 min/h = 58.2 min]

11. (10.50 mgd × 1,000,000 gal/MG ÷ 24 h/d ÷ 60 min/h ÷ 7.48 gal/ft^3) [974.82 cfm] ÷ (60 ft × 11 ft × 2 units) [1,320 ft^2] = 0.74 fpm

12. (4,750 gpm × 60 min/h × 24 h/d) ÷ (355 ft × 2 units) = 9,633.8 gpd/ft
(6,840,000 gpd; 710 ft²)

13. 10.50 mgd × 1,000,000 gal/MG ÷ (60 ft × 180 ft × 2 units) = 486.1 gpd/ft²

14. (10.50 mgd × 1,000,000 gal/MG ÷ 24 h/d ÷ 60 min/h ÷ 7.48 gal/ft³) ÷ (10 ft × 10 ft × 2 units) = 4.87 fpm
(974.82 cfm; 200 ft²)

15. (10 ft × 65 ft × 10 ft × 7.48 gal/ft³ × 2 units) ÷ (7.15 mgd × 1,000,000 gal/MG ÷ 24 h/d ÷ 60 min/h) = 19.58 min *or* 19 min 35 s
[0.58 min × 60 s/min = 34.8 s]
(97,240 gal; 4,865.3 gpm)

16. (17.5 mgd × 1,000,000 gal/MG ÷ 24 h/d ÷ 60 min/h) ÷ (25 ft × 30 ft) = 16.2 gpm/ft²
(12,152.8 gpm; 750 ft²)

17. 16.2 gpm/ft² × 1.6 in. of rise/gpm/ft² = 25.9 in. of rise

18. 100% – [(7.15 mgd × 1,000,000 gal/MG) – (5,168,000 gal/month ÷ 30 d/month) ÷ (7.15 mgd × 1,000,000 gal/MG) × 100] = 2.41%

19. (50 ft × 50 ft × 21 ft × 7.48 gal/ft³) ÷ (5,168,000 gal/month ÷ 46 wash/month) = 3.49 *or* 3 washes
(392,700 gal; 112,347.8 gal/wash)

20. (50 ft × 50 ft × 21 ft × 7.48 gal/ft³) ÷ 750 gpm ÷ 60 min/h = 8.73 h *or* 8 h 44 min
[0.73 h × 60 min/h = 43.8 min]
(392,700 gal)

21. (155 ft × 295 ft × 16 ft × 7.48 gal/ft³) ÷ (10.50 mgd × 1,000,000 gal/MG ÷ 24 h/d) = 12.51 h *or* 12 h 31 min
[0.51 h × 60 min/h = 30.6 min]
(5,472,368 gal; 437,500 gph)

22. 190 ft × 610 ft × 5 ft × 3 units ÷ (3,178,200 gal/month ÷ 30 d/month ÷ 7.48 gal/ft³) = 122.75 days
(14,163.1 ft³/d)

23. 6,289 lb/month ÷ 30 d/month ÷ 8.34 lb/gal ÷ 7.15 mgd = 3.5 mg/L

24. 3.5 mg/L – (1.2 mg/L + 0.1 mg/L) = 2.2 mg/L